SUB – SONICS

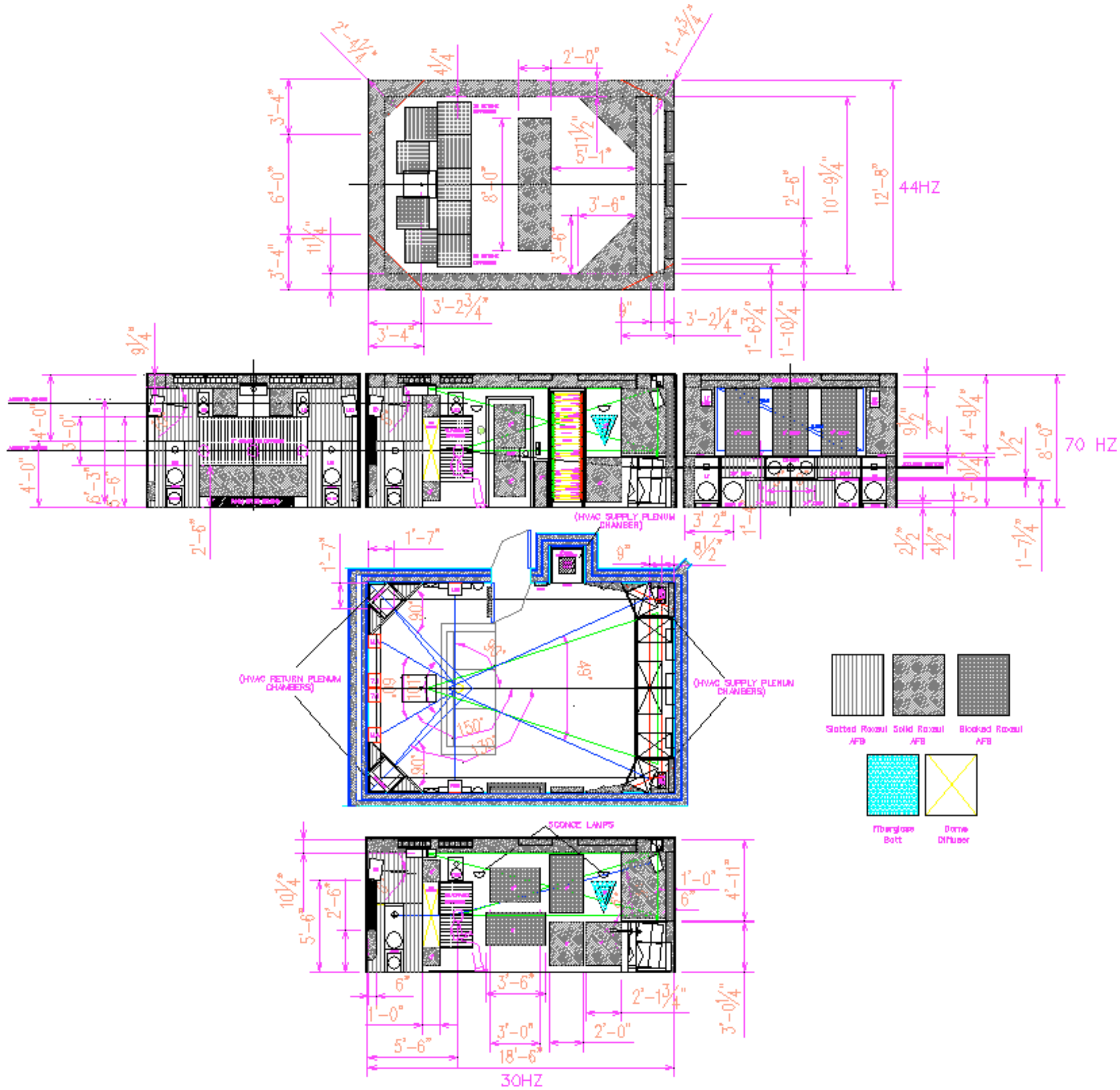
AKA: The Tale of Four Subs

SVS PB12NSD

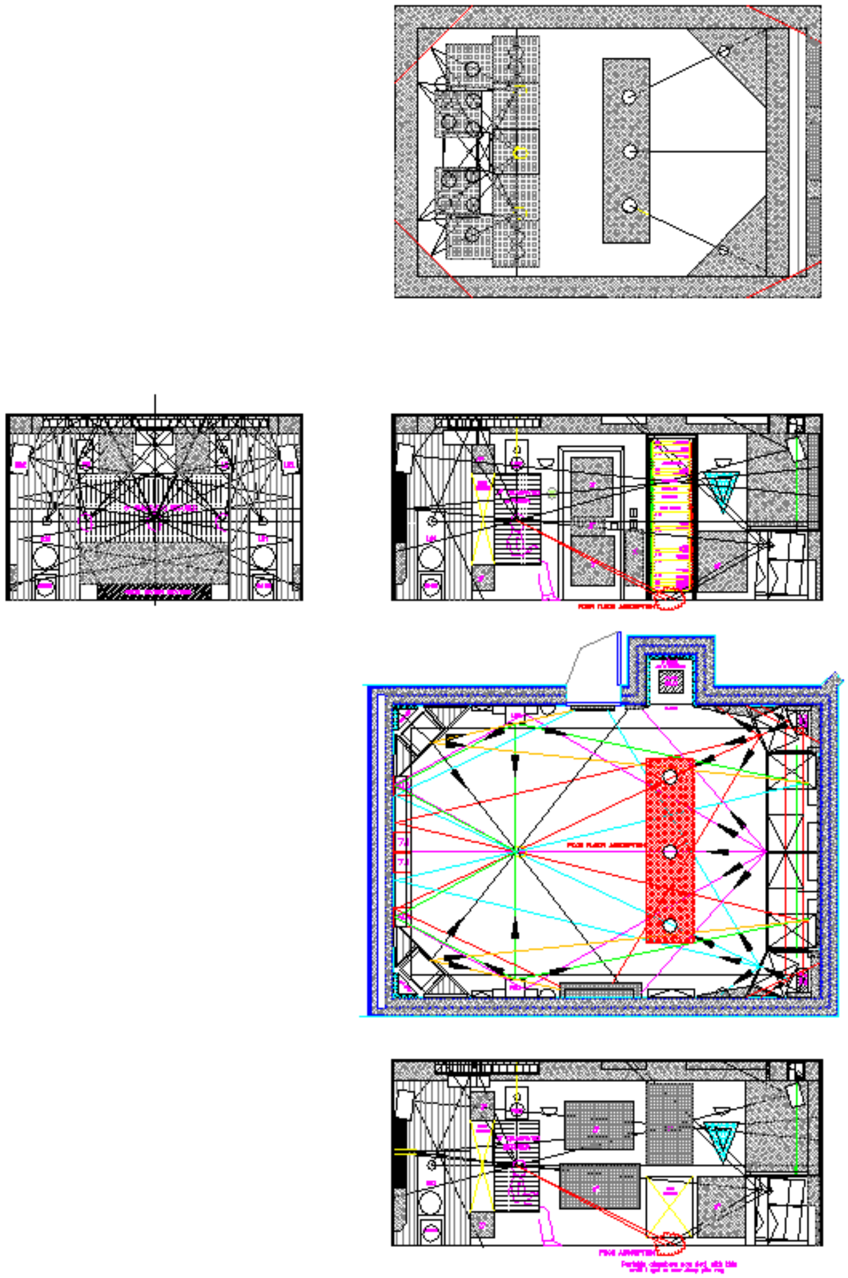
SVS SB2000

Introduction

Just as a reminder the following is my current room design:



Current Room Layout



Current Room Design Showing the Primary Reflection Points

With the desire to improve my LF decay, sub frequency response and extension, I decided to add two additional subs. However, due to the room's layout it was only possible to add another two smaller sealed subs at the rear corners of the room – see above. I therefore opted to add two sealed 12" SVS SB2000's to the existing pair of ported 12" SVS PB12NSD's.

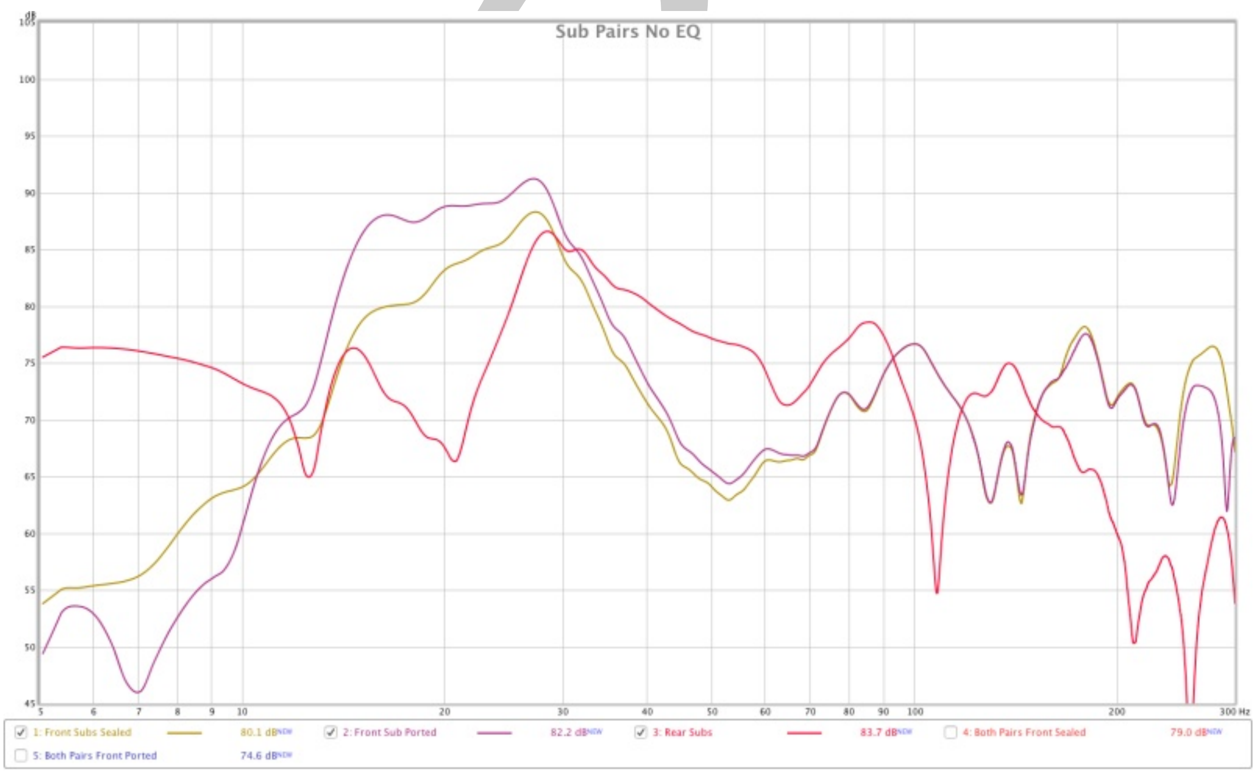
The following details my trials and tribulations of integrating four subs (two vented and two sealed) and to creating the rooms' final response with their integration with the satellites, as if anything is final with this hobby!

After several discussions with Ed Mullen and Sonnie at SVS it was clear that Ed, in particular, was adamant about not doing this due to the significant difference in the group delays and LF roll-off of each pair of subs. Ed stressed that the integration of these two pairs of subs may be challenging, this was to become quite an understatement and I wish that I had listened to him. Ed even extended my return period due to the problems I was having, now that's service and support. The challenges were however overcome, and eventually the four subs integration with each other, and the system as a whole, approached what I was looking for.

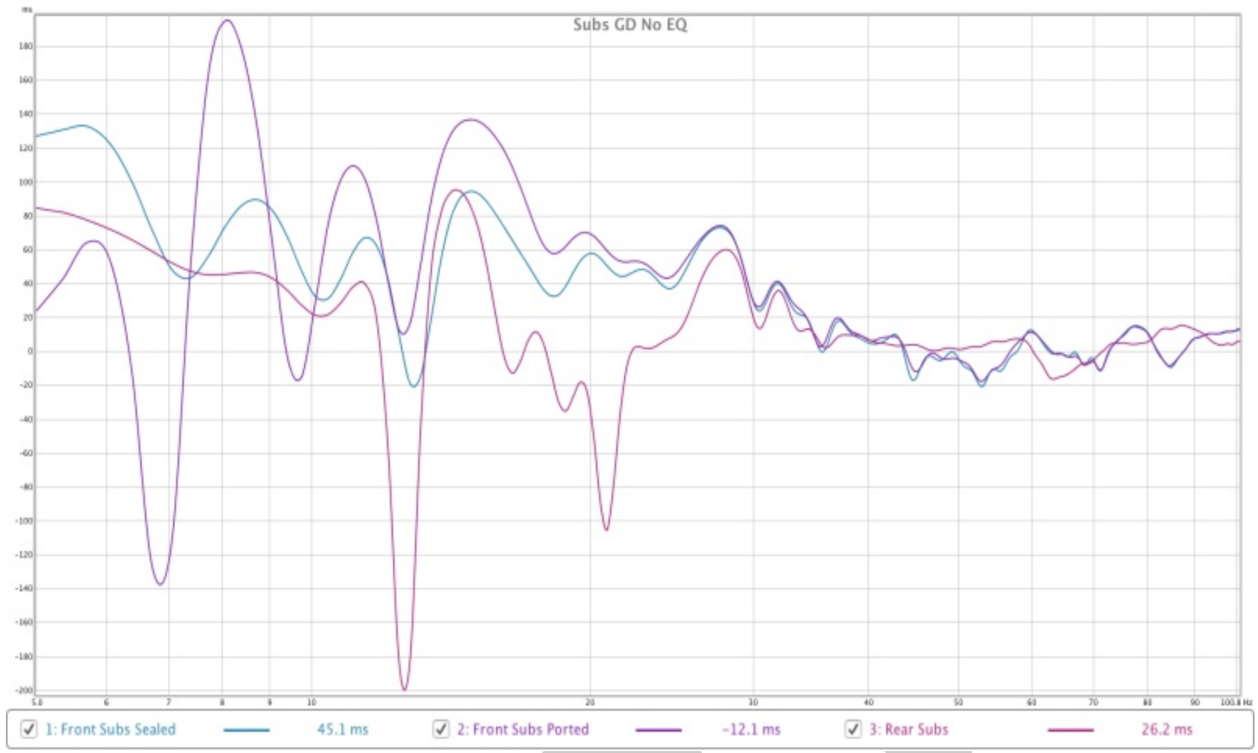
I realize that my experience MAYBE different to you the reader, and my room acoustics are unique to me, but my measurements will clearly show the difficulties that show up when equalizing and mixing subs. My advice to anybody thinking of mixing subs be it types, sealed or ported, sizes or manufacturers, is **DON'T DO IT**, their integration is not straightforward. Audyssey, in my opinion, is not suitable to achieve an optimum integration of different subs that is even close to satisfactory. This is due to the way it treats both the LF roll-off and averages many measurements. All I can say is thank goodness for the REW EQ program. It is an outstanding piece of software, kudos to John Mulcahy the author.

Pre-Audyssey Measurements

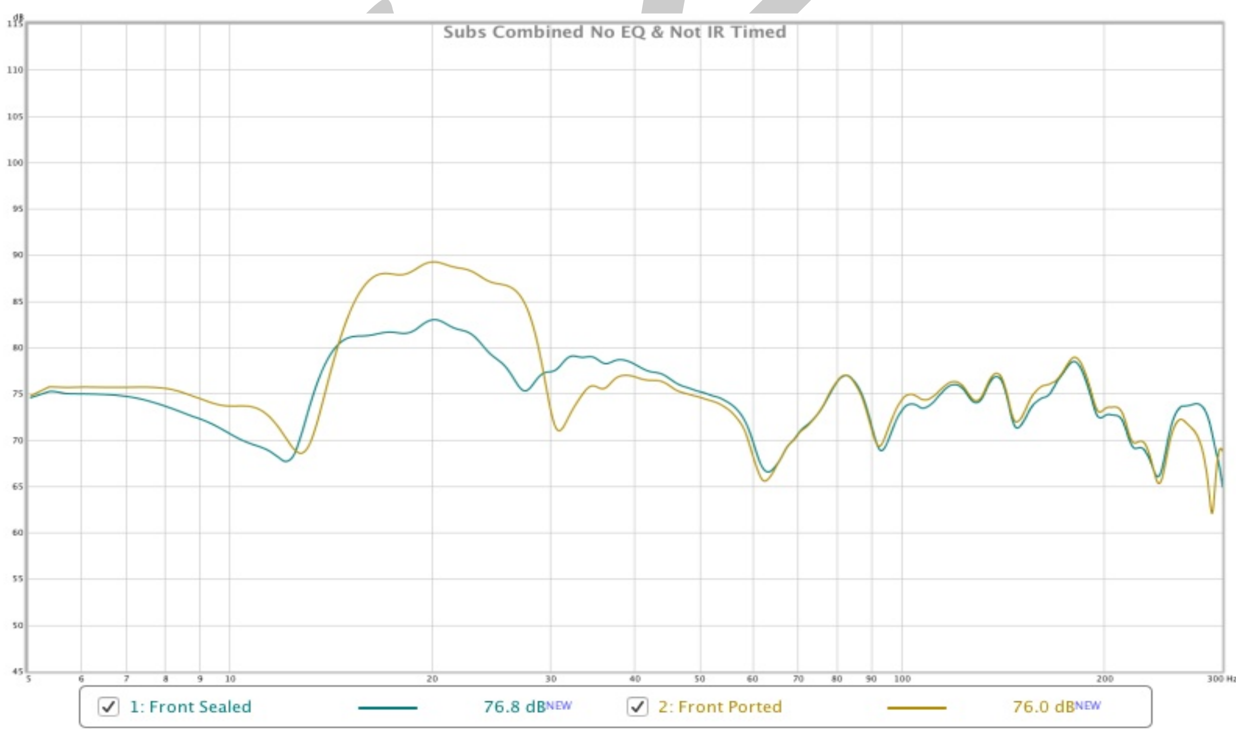
For reference, the following are 'raw' non-equalized measurements of the sub pairs driven directly by REW with the fronts ported and sealed. Each individual sub was first level matched (75dB) at the MLP.



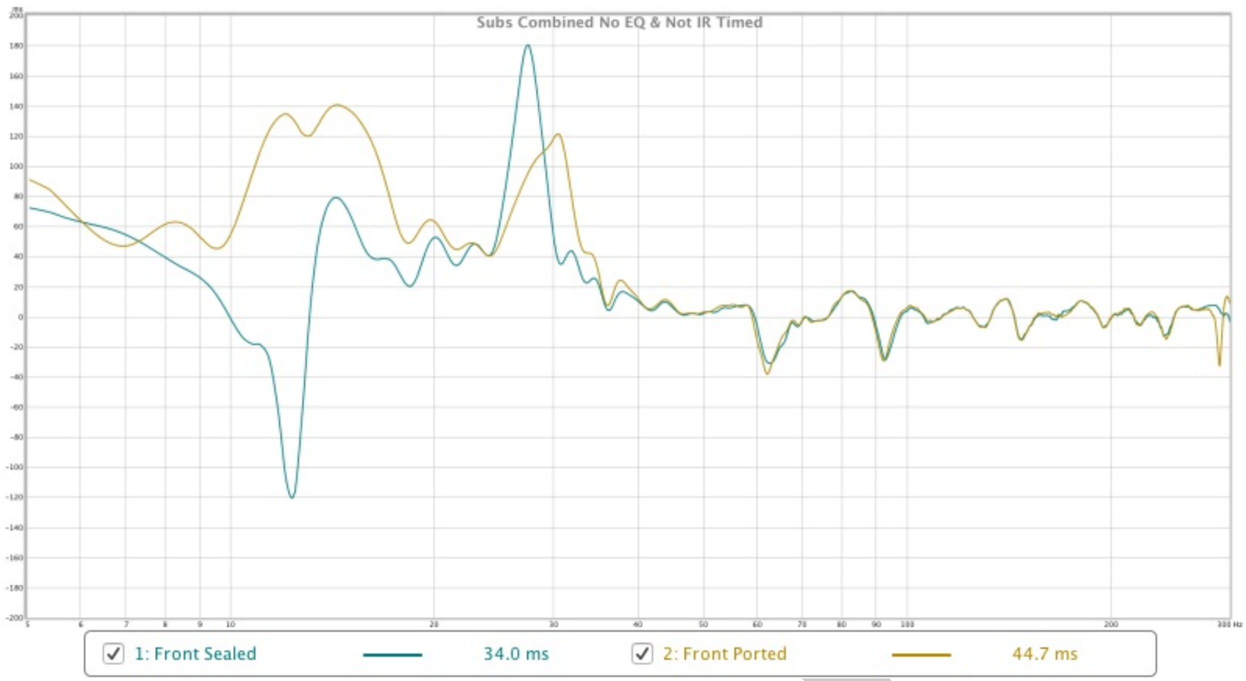
1. Sub Pair Frequency Responses. Red-SB2000. Yellow-PB12's sealed. Purple – PB12's ported.



1A. Sub Pair Group Delays



1B. Subs Combined Frequency Response – PB12's sealed & ported. No EQ and no impulse alignment.



1C. Sub Combined Group Delays – PB12's sealed & ported. No EQ and no impulse alignment.

The group delay difference is quite pronounced at lower frequencies per Ed Mullen's warning. Note how:

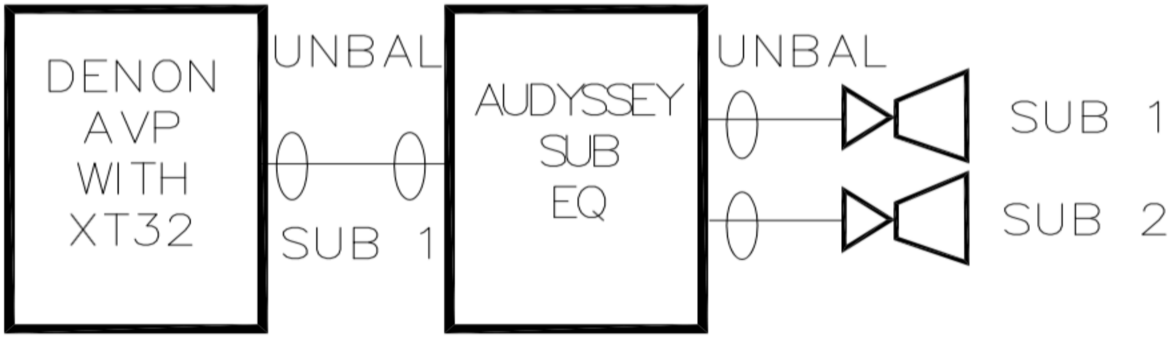
1. Sealing the front subs create a Group Delay *closer* to that of the rears, but obviously at the expense of LF output. Graph 1A.
2. Combining both pairs provides a much smoother frequency and group delay response. Graphs 1B & 1C.

Room resonances are clearly observable in Graph 1 at approximately 16Hz, 28Hz and 30Hz. The flatter sealed frequency response shown in Graph 1B doesn't look terrible but sounded awful. Clearly time alignment and EQ would be required in order to optimize their performance.

Initial Approach

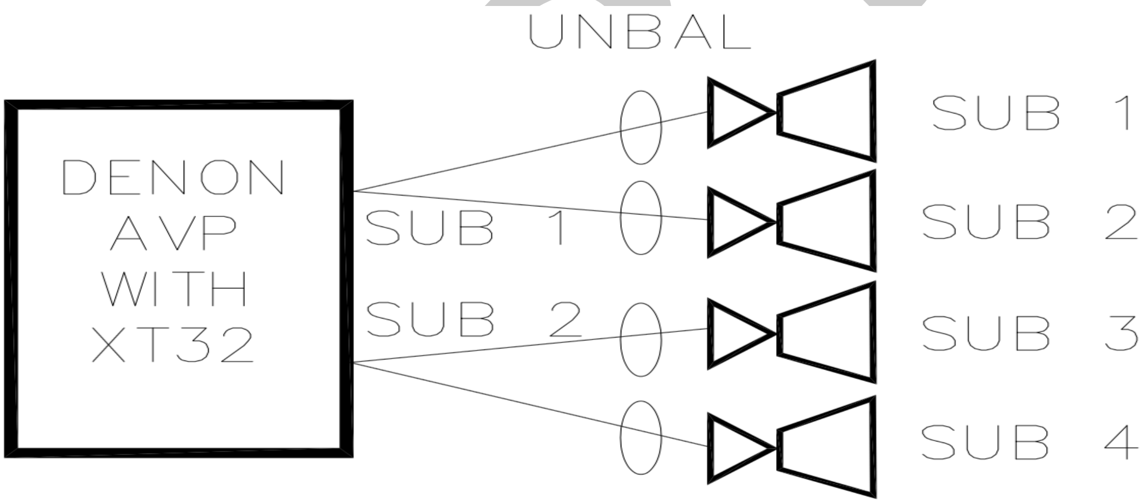
The following is a brief overview of my initial approaches that took literally a couple of hundred sweeps. The final successful approach follows this; it took a lot longer with more than double the number of measurements.

Just using Audyssey XT32 in my Denon AVP-A1 did not produce a satisfactory frequency response from my original two subs, nor did they ever sound very clean. I ended up using a stand alone Audyssey Sub EQ, to pre-EQ the subs first, as one in and two out, treating both subs as one, and then running Audyssey in the AVP driving the Sub EQ when I equalized the satellites. This arrangement is shown below:



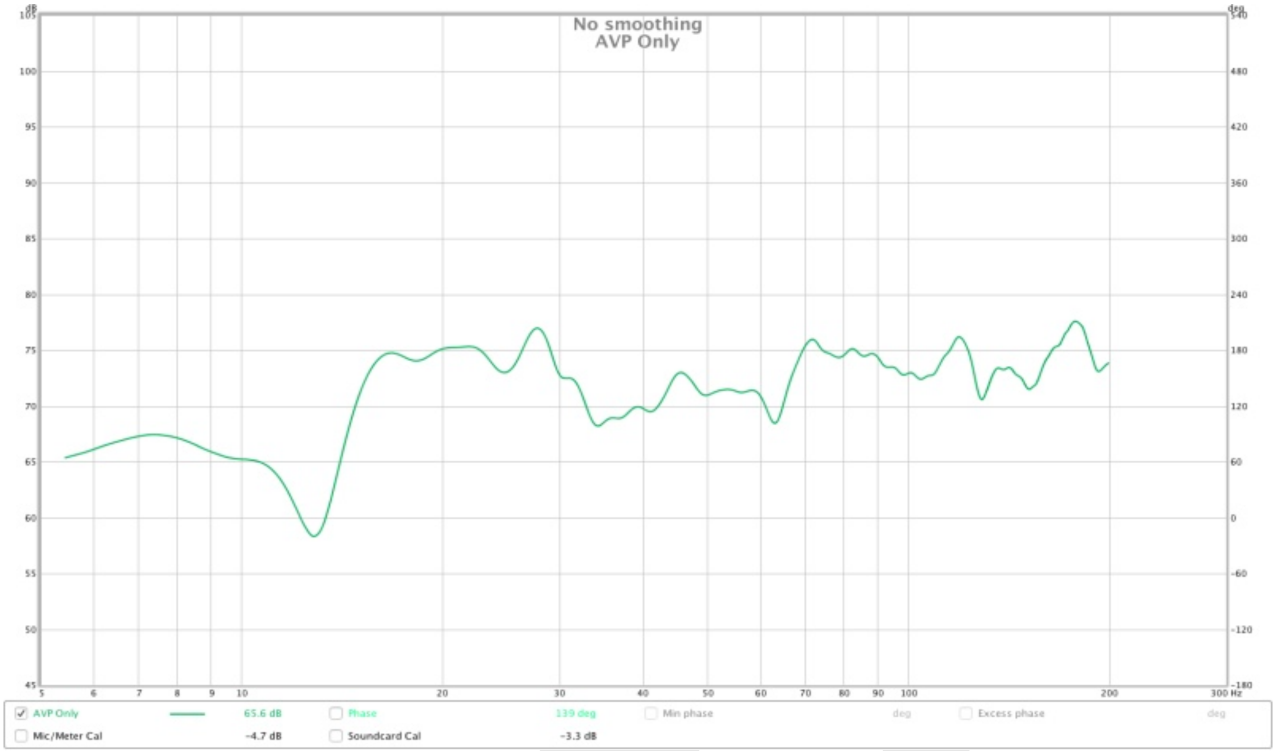
2. Original Sub Connectivity – 1 pair

Having had reasonable success with this approach to EQ my two subs (see earlier post graphs) I believed that this approach would work for the four (Ed Mullen didn't think so – he was correct). I even called Audyssey and they recommended that I *only use the AVP* and EQ them as two pairs, wired as shown in the following diagram.

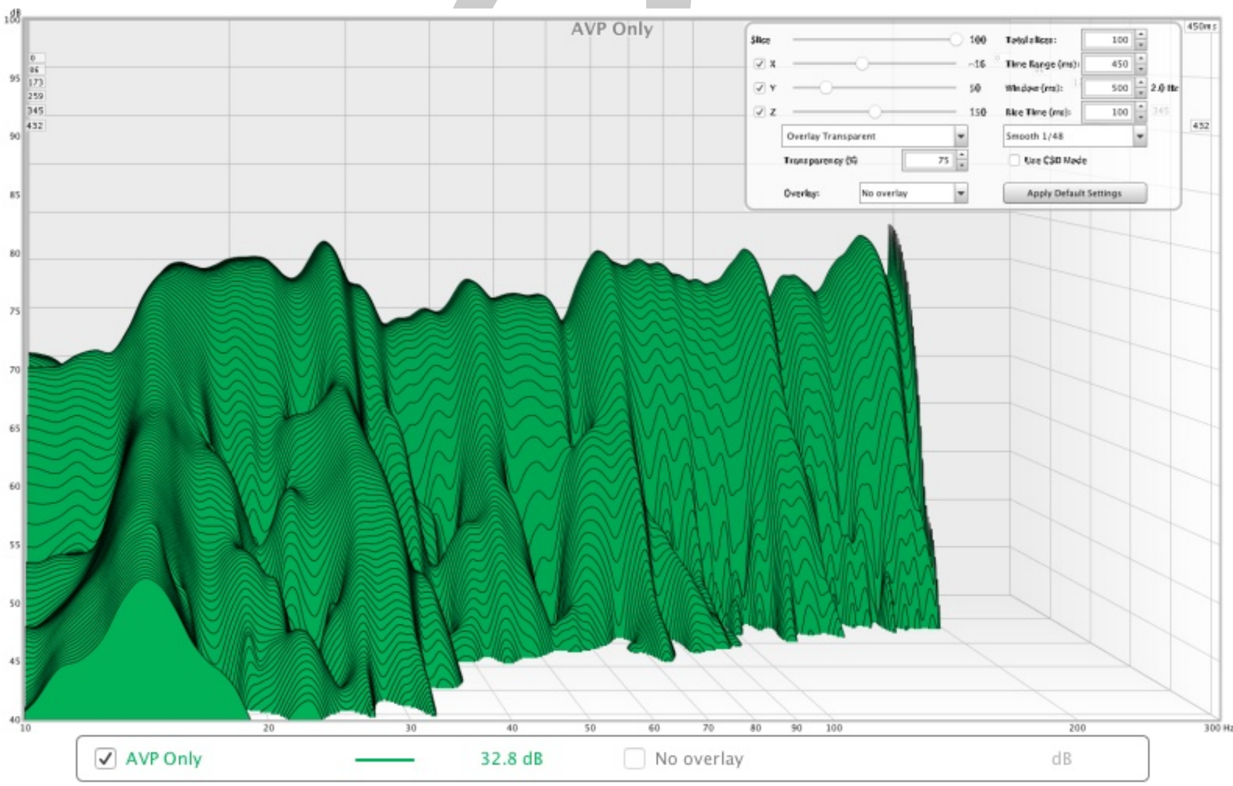


3. AVP Sub Connectivity – 2 sub pairs driven by 2 independent sub outputs

Having been advised by Audyssey that the above approach would be the best approach I went ahead and tried it. Each sub was first SPL matched (75dB) at the MLP. The REW sweep was applied to the External AVP inputs running in DSP mode. This approach was poor. After optimizing the sub levels and delays it was dismissed as the frequency response and waterfall shown below could not be improved upon. Clearly both are poor and there are no observable benefits of using the additional pair of SB2000's.



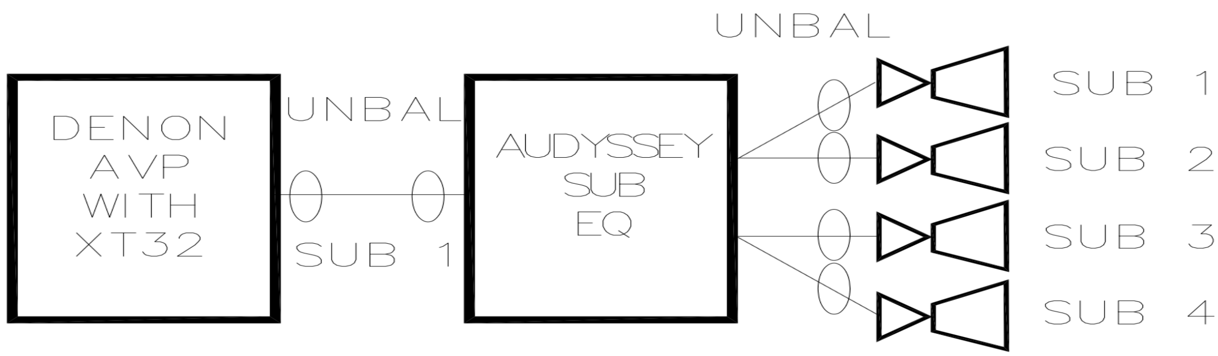
3A. AVP Only Frequency Response (no external sub pre EQ)



3B. AVP Only Waterfall (no external sub pre EQ)

Revised (Original) Approach

I therefore returned to pre-equalizing the subs prior to running Audyssey XT32 in the AVP. For these tests the REW sweep was applied **directly** to the Audyssey Sub EQ. I did not want the AVP to influence the measurement results.

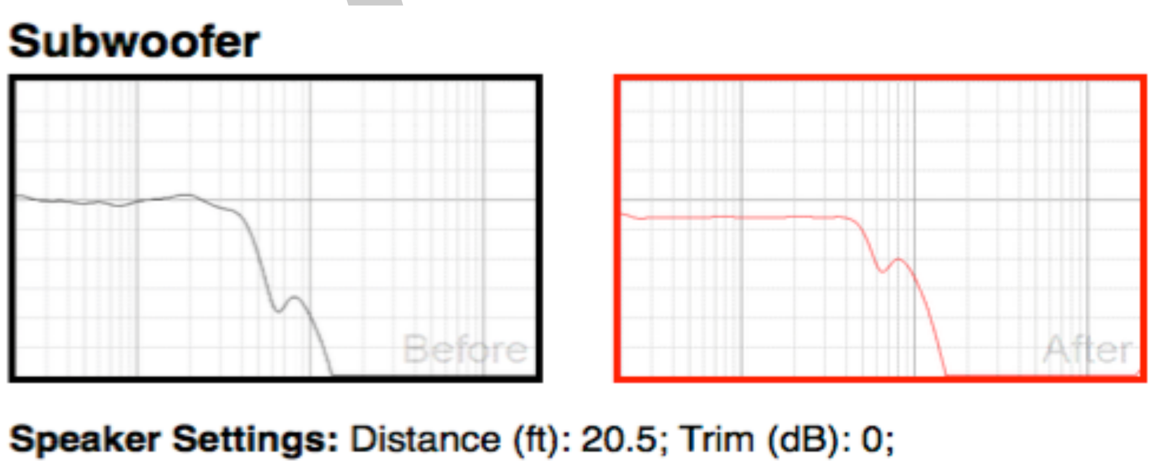


4. Revised Sub Connectivity – 2 pairs

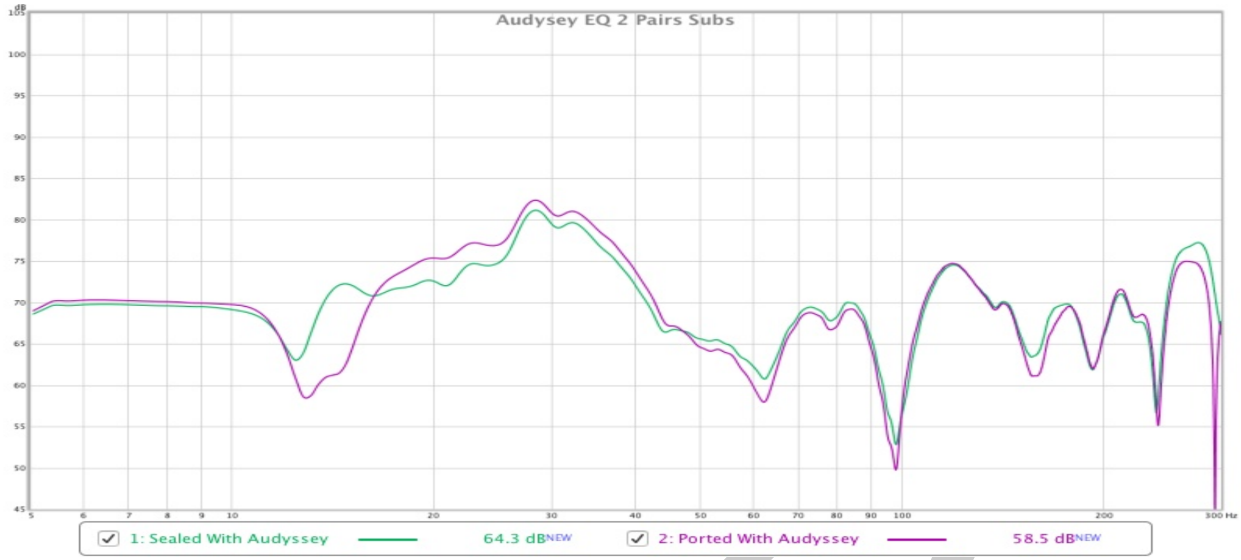
Each individual sub was level matched (75dB) at the MLP and then the external Audyssey Sub EQ was run as one in - two out, each output driving a sub pair as shown above to provide:

- Pair level matching
- Relative pair sub timing correction
- Preliminary combined 4 sub EQ

Many combinations of mike position and height were tried, but not clustering the mic for at least 8 measurements in a two foot square area around the MLP at ear height always made the frequency response when measured with REW worse. *This despite the Audyssey graphs always being virtually flat*!



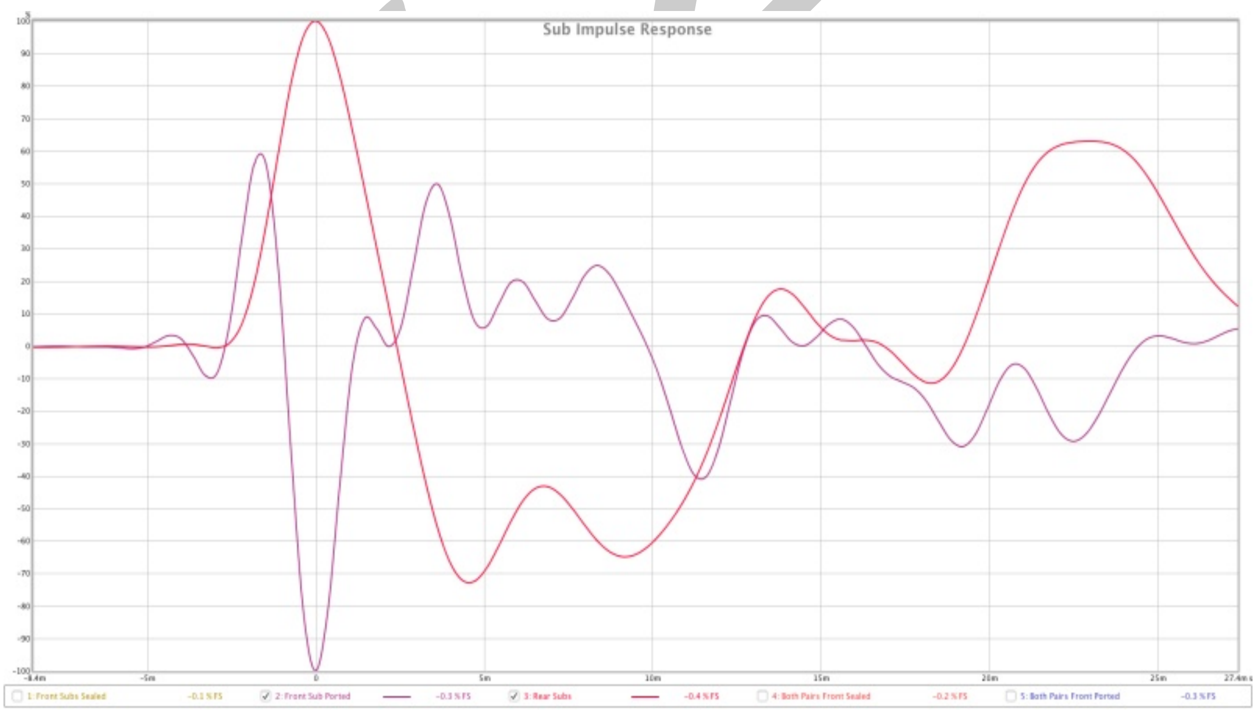
5A. Typical Audyssey Sub EQ Predicted Frequency Response Graph – PB12 subs ported



5B. Typical REW Frequency Response with Audyssey Sub EQ – ported & sealed

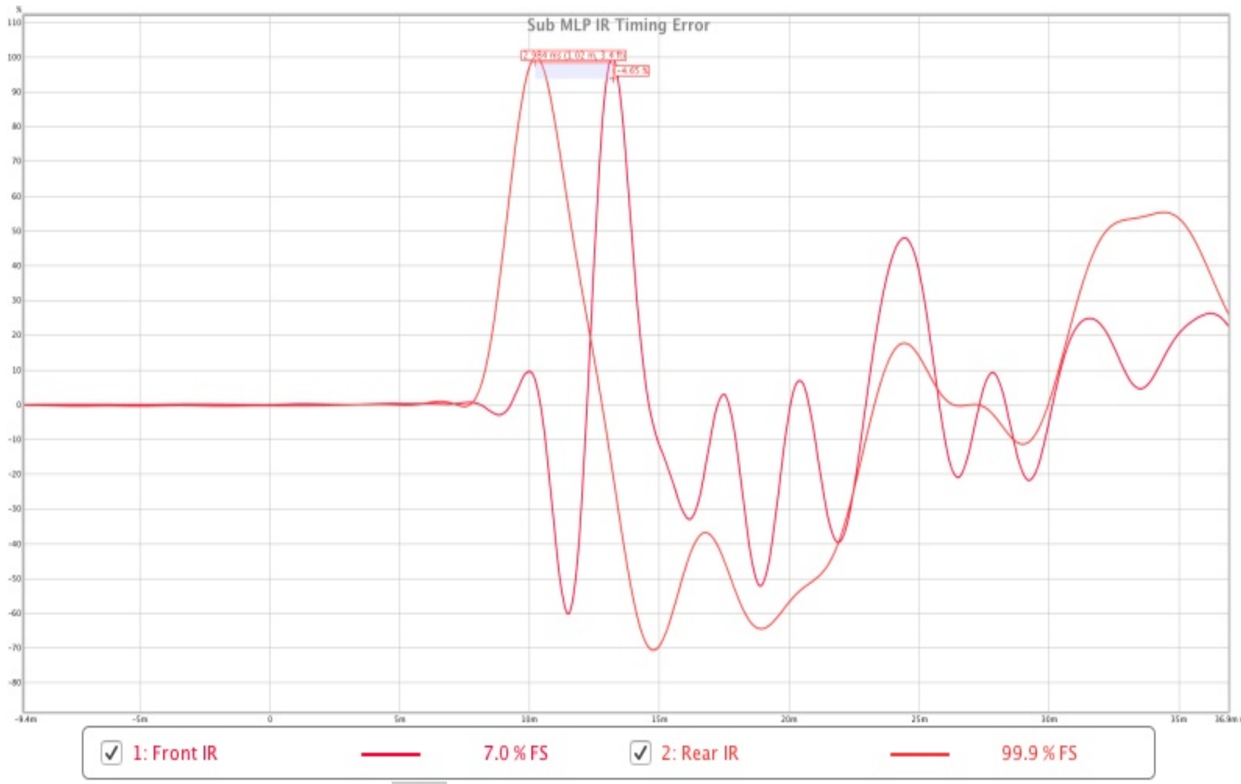
The similarity between the predicted Audyssey graphs 5A and measured REW graphs 5B is less than stellar!

After examining the impulse responses it appeared that there was a phase inversion between the two pairs of subs. At no time did Audyssey complain about the relative phase inversion shown in the following graph:



6. Sub Pairs Impulse Response – Red PB12 subs. Purple SB2000 subs. (no loop back was used, so there is no relative timing information)

There were no wiring errors external to the subs, so the fronts were initially phase inverted believing that the rears were correct, only later to determine that it was actually the rears that were phase inverted. I discovered that I had been driving the system from the *inverted output* from my REW USB interface balanced line output. Once the phase inversions were rectified the unaligned impulse responses without EQ are shown below:

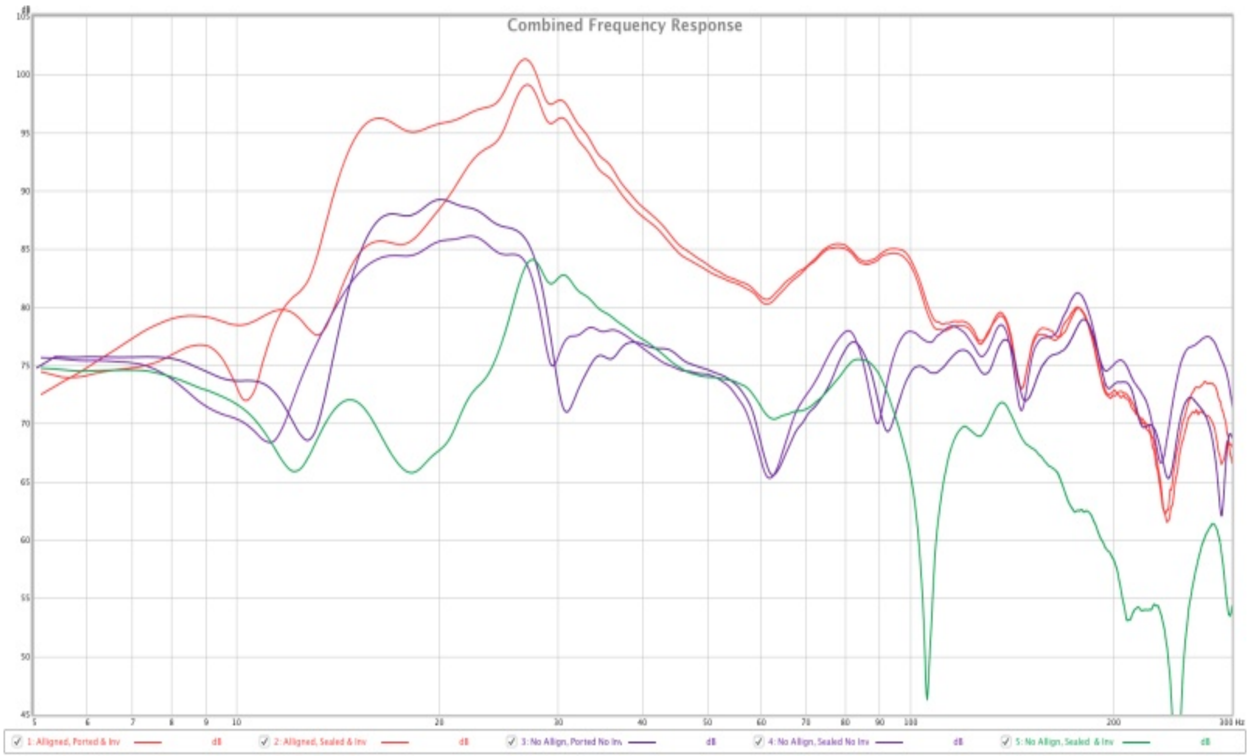


6A. Impulse Response Timing Error of Approximately 3mS – rears phase inverted

It was believed (although never measured, as at that point in time I was not using loopback) that Audyssey Sub EQ corrected this timing error, but obviously not the inversion.

Any attempt to polarity and time align the front subs first smaller -60% impulse with the rears impulse resulted in a poor combined frequency and impulse response that did not equalize well.

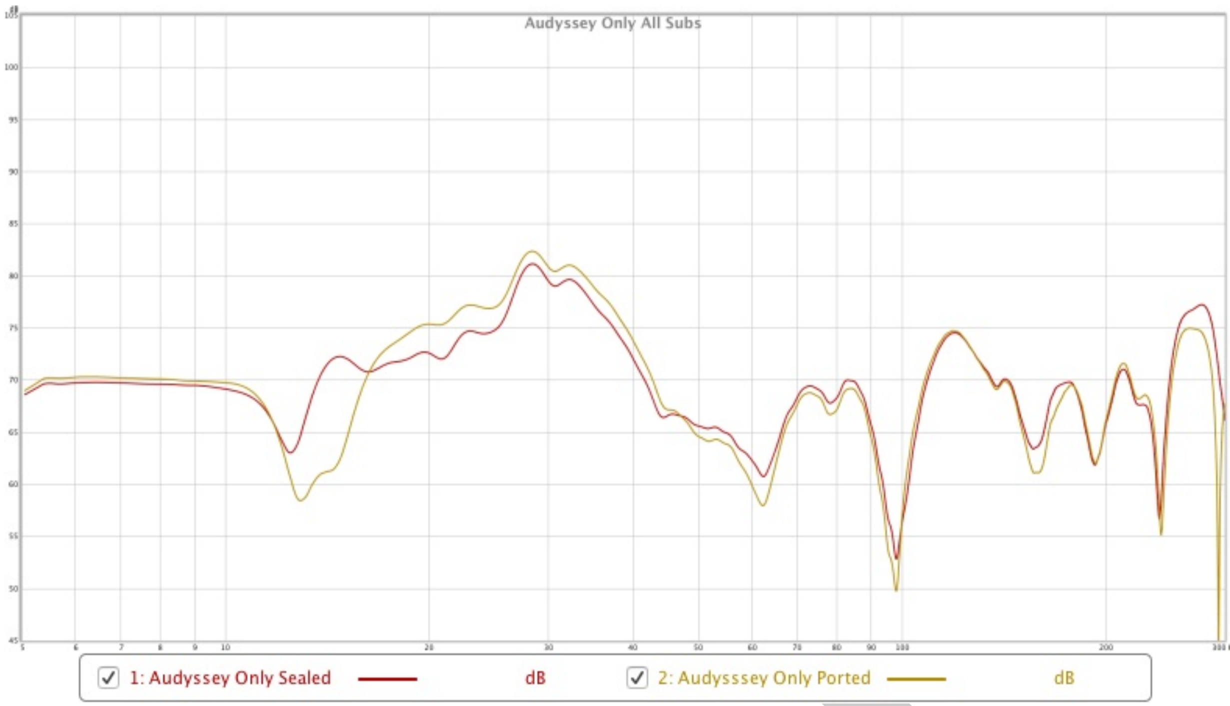
The following graph is included for reference only. It was created using external delay hardware to match the above impulse responses and does NOT include any EQ. It is included to show the effect on the frequency response of correctly aligning both the phase and impulse responses.



6B. Sub Pairs - Frequency Responses with no EQ. Green – PB12's sealed & not IR aligned with SB2000's. Purple – SB2000 not inverted with the PB12's ported and sealed. Orange – PB12's sealed & aligned. Red – PB12's ported & aligned, SB2000's inverted.

It can clearly be seen that aligning the subs impulse responses and correcting the phase error significantly increase both the LF and mid band energy and the level of the resonances, particularly, when the fronts are ported. Deliberately misaligning the impulse response and phase to create a flat response for several subs is NOT an acceptable method of doing so. The resulting impulse and room decays became very poor and made the bass thick/muddy and unnatural.

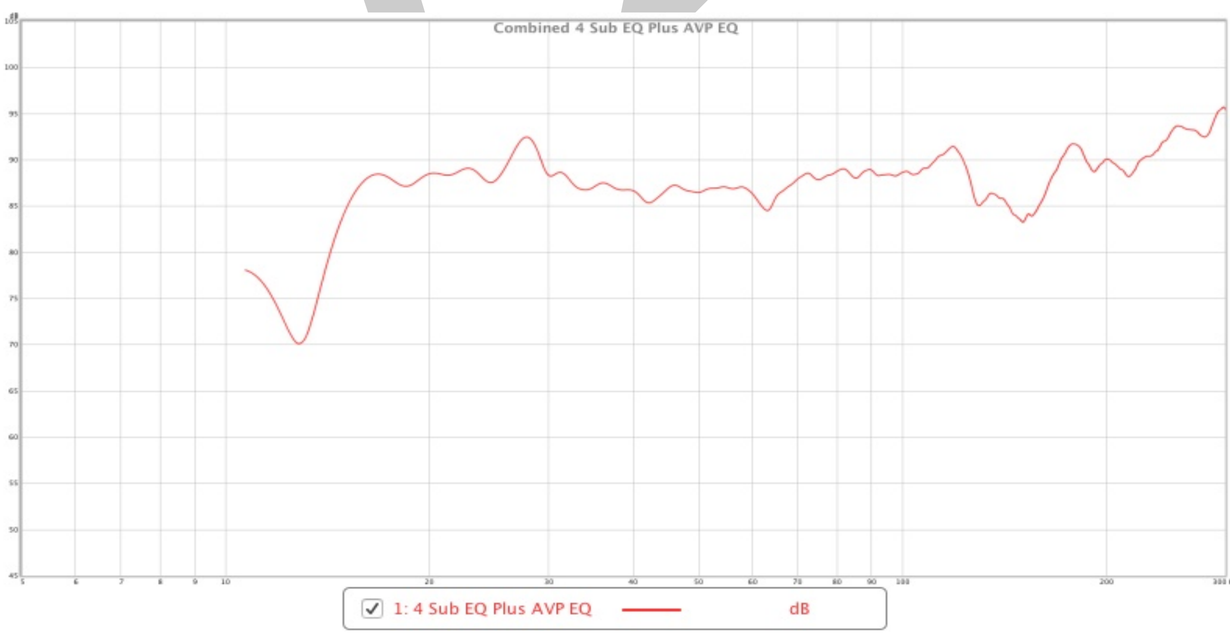
To cut a very long story short continued Audyssey sweeps with the *corrected* polarity produced no significant improvements in the frequency response or resonance decay times. After examining many ported and sealed responses, and listening to the final equalized results, it became obvious that leaving the fronts ported produced the better sounding bass results.



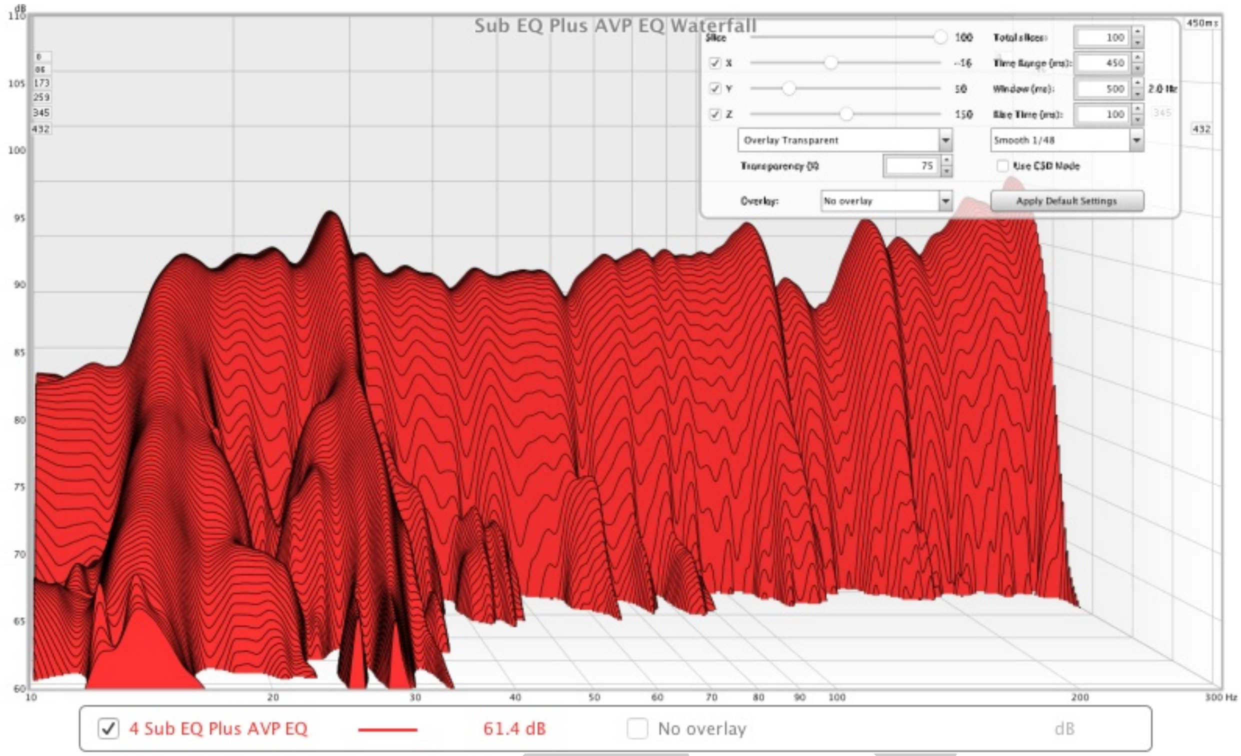
7. Flattest Four-Sub Frequency Response – ported & sealed with Audyssey Sub EQ

The above response is clearly poor and could not be improved upon by altering the microphone positions or number of measurements.

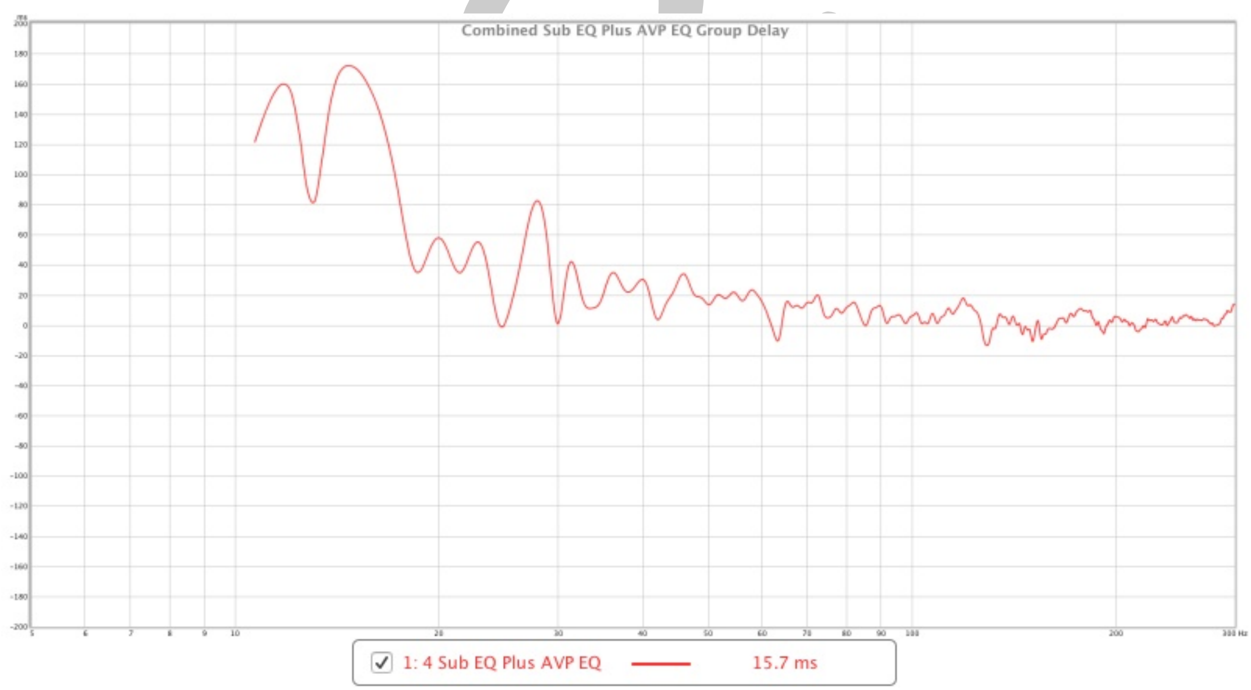
The following graphs are the final result using the flattest Audyssey Sub EQ response obtained (Graph 7) and then running the AVP XT32 EQ:



8. Sub Frequency Response - Sub EQ and AVP with Pro



8A. Sub Waterfall - Sub EQ and AVP with Pro – Poor decay at 16Hz, 27Hz and 30Hz.



8B. Sub Combined Group Delay - Sub EQ and AVP EQ using Pro.

Clearly, neither the frequency response nor waterfall shows any significant improvement over my original two PB12NSD subs (see earlier post graphs) and no real improvement in LF extension.

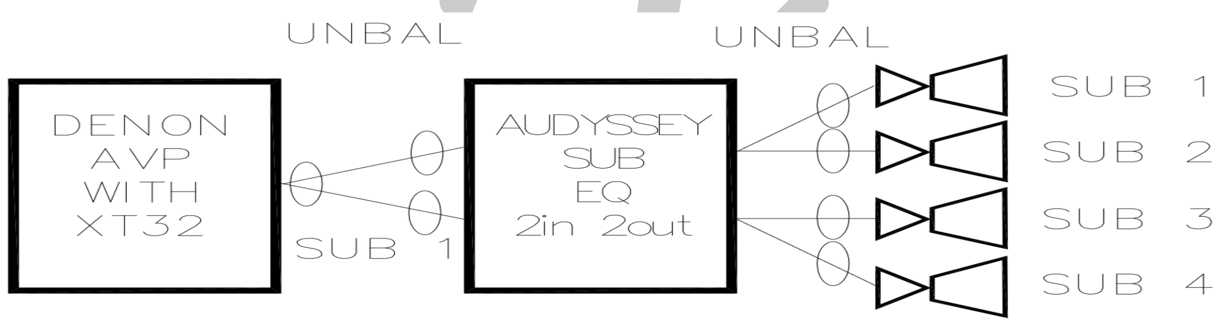
The rising group delay is as expected, and deserves no further comment at this stage other than to point out that the swings below about 20Hz are a function of both the LF sub-sonic roll-off and protection filters in the subs electronics and the rooms resonances.

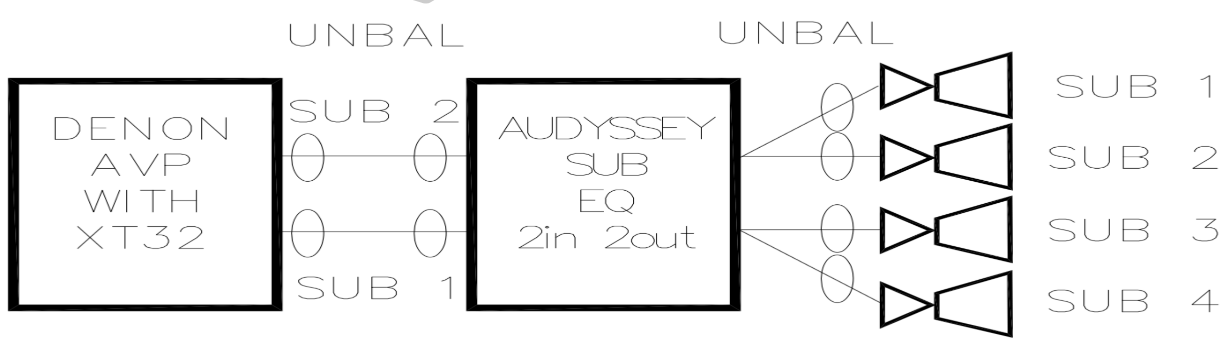
All the previous graphs clearly show the rooms main decay problems at approximately 16Hz, 27Hz and 30Hz, something Audyssey did not significantly improve. (*Ideally, moving the subs may have improved this, but this was not an option and their current locations were very close to recommended positioning as shown in a number of well-known white papers).* Furthermore, there was no usable improvement in the LF extension below 15Hz.

Note: Repeat sweeps were made after setting the rear subs at 25% in from the sidewalls to match the fronts; this is a preferred 4-sub arrangement. It produced no significant benefits, messed up the rooms appearance and WAF, so was immediately dismissed and the subs returned to the rear corners.

Against my better judgment I then repeated all the tests again with the Sub EQ operating as two separate channels, two in - two out; EQ'd each pair *separately* and then ran the AVP to EQ all 4 subs at the same time with:

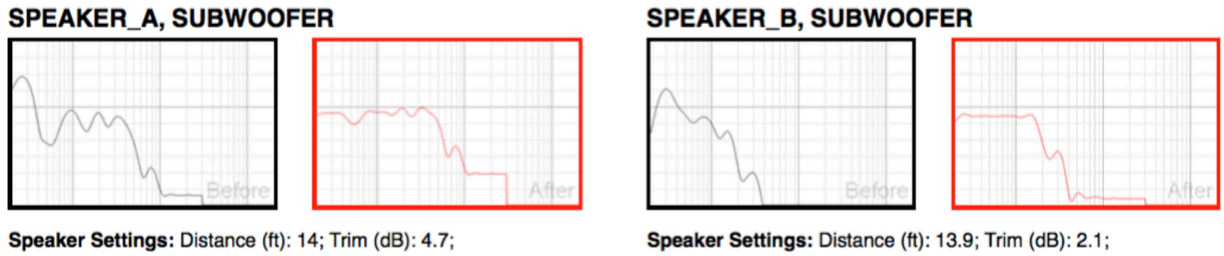
1. AVP sub 1 output driving both inputs (Y split) on the Sub EQ - (relative sub delays could not be adjusted via the AVP)
2. AVP sub 1 and sub 2 outputs driving each Sub EQ input independently - (relative sub delays and levels could be adjusted using the AVP)





9. Alternative Sub Connectivity's

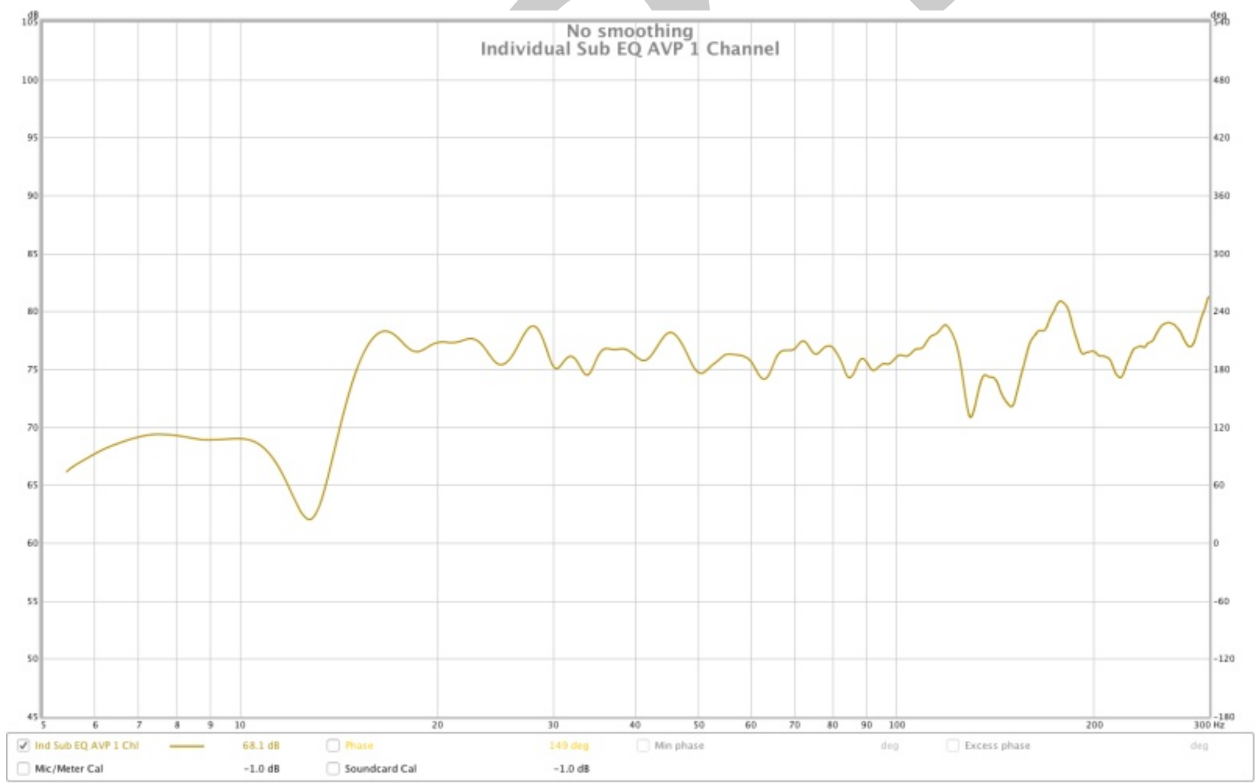
The resulting *predicted* two Channel Audyssey Sub EQ graphs:



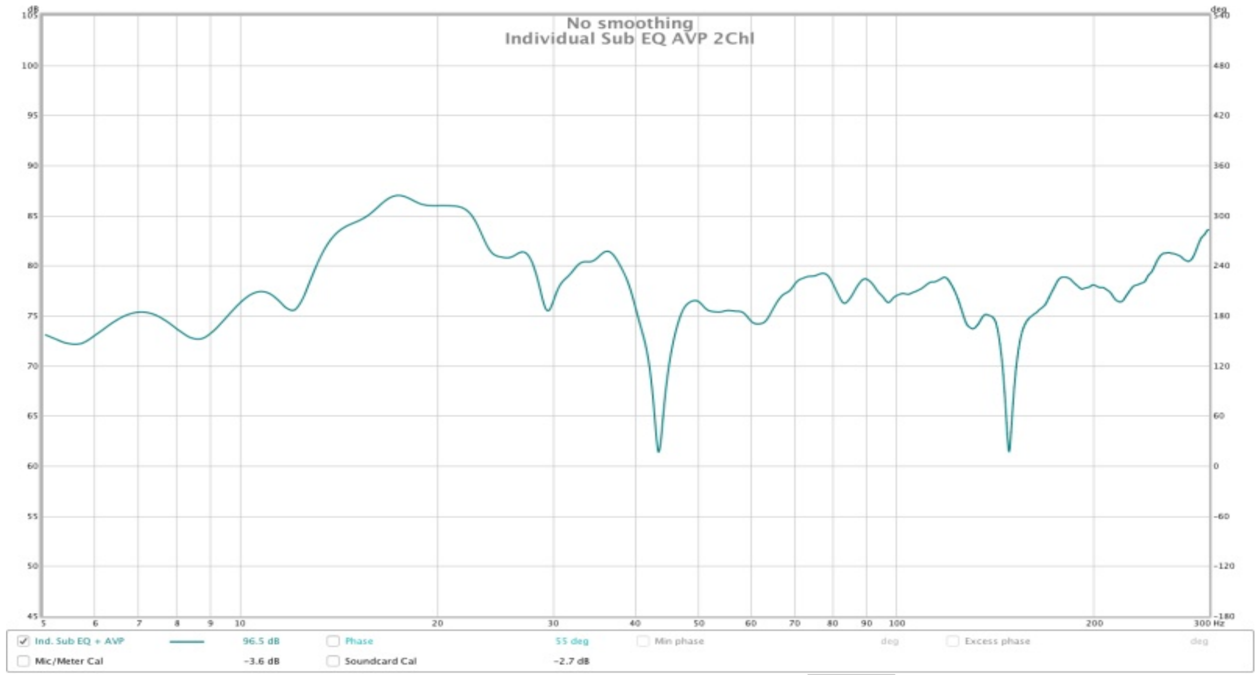
10. Audyssey Sub EQ Only Frequency Responses - 2 in / 2 out Sub EQ channels. Speaker A – rear SB2000 pair, Speaker B - front PB12 pair

Neither arrangement gave me the required integration, LF extension and improvements in decay times that I was looking for below 40Hz.

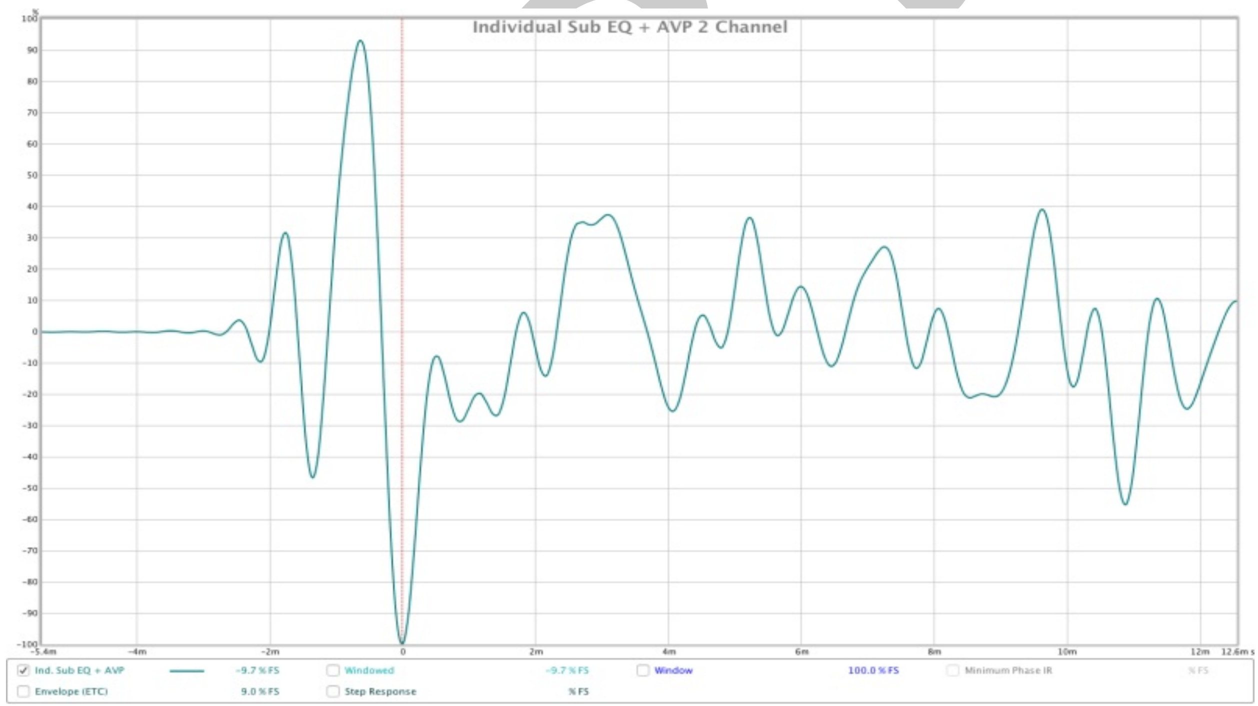
The following graphs show the resulting responses after the AVP had been run driving both Audyssey Sub EQ channels:



10A. Sub Combined AVP Frequency Response - 1 in / 2 out Sub EQ channels



11. Combined AVP Frequency Response - 2 in / 2 out Sub EQ.



11A. Combined AVP Impulse Response - 2 in / 2 out Sub EQ.

There is clearly still no *significant* improvement in the combined subs responses with either approach even though the 2 in / 2 out approach allowed me to raise the LF response below 15Hz (Graph 11). This approach produced a very poor impulse response (Graph 11A) as I had to significantly misalign the impulse responses and relative sub levels to achieve the reasonably flat frequency response.

The real issue is that while Audyssey can produce a reasonably flat LF response, and you can use the distance setting in the AVP to get the delays of the sub pairs time aligned (or not), it didn't significantly improve the three resonances described earlier and more often than not made them worse. The measurement area was only four square feet at the MLP. Spreading the measurement over a wider area made most responses at the MLP worse. Some mic positioning, while creating a flatter LF response, produced very poor decay times making what looked reasonable in the frequency domain sound dreadful. Also, as seen in graph 11A, the impulse response is exceptionally poor, which I am sure added to the poor bass quality.

Audyssey Restrictions

The much bigger restrictions are that Audyssey:

- Averages the frequency response at multiple locations, weighting acoustical errors according to their type and severity. Therefore, while providing a wider improved listening area (what it is designed for), never (well at least for me) optimizes the systems response at the MLP or any other location!
- Will not EQ below where it finds the combined subs LF -3dB roll off point. Why is this an issue? I wanted to extend the LF response as the SB2000's in the corners provided a usable extension to below 10Hz. When you add dissimilar subs your mid band LF level goes up by typically 6dB BUT the added LF extension is only on one pair of subs so there is no corresponding level increase at lower frequencies as the lesser sub has little output there. When Audyssey EQ's this mix of subs it still measures the lesser subs LF roll off. Utilizing the better subs LF response is therefore not possible, as the four subs now provide an additional 6dB LF mid-range output causing Audyssey to reduce the overall level providing:
  a) More headroom
  b) Lower distortion
  c) Little improvement in LF extension as all sub levels are reduced

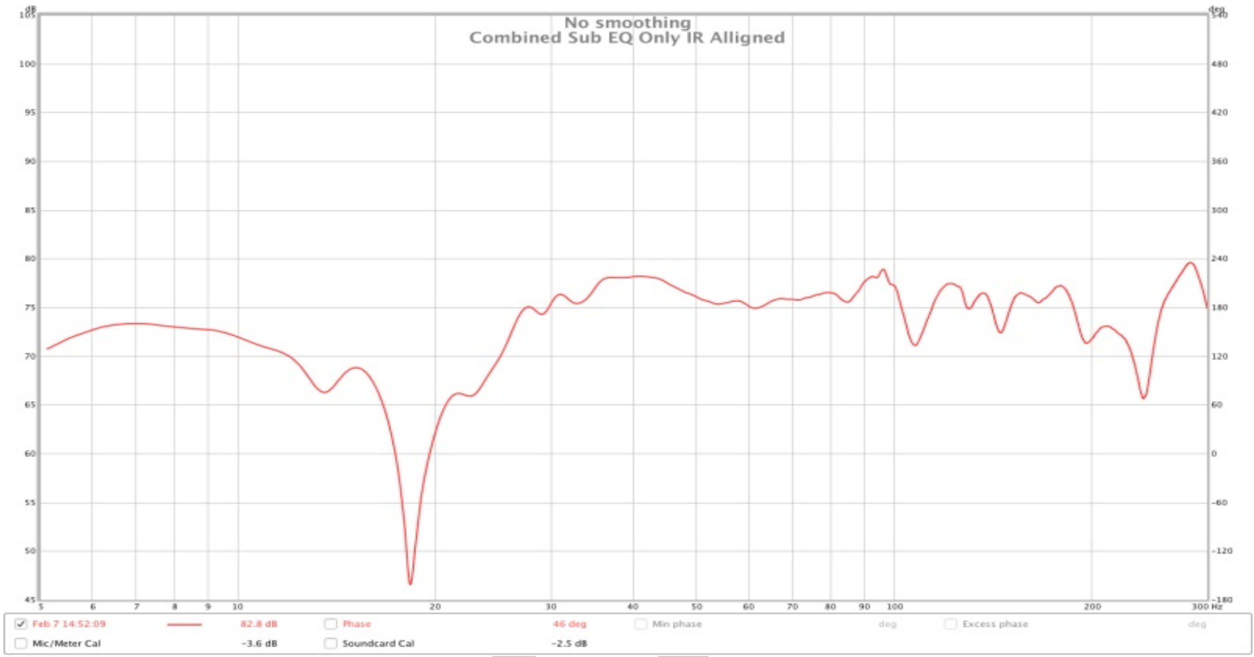
  Adjusting levels so that the better subs have more output and therefore their LF level is affectively higher is:

  1. Self-defeating, especially if equalizing as a set of four as opposed to two pairs – think about it!
  2. Can cause localization of the louder subs
  3. Reduces the headroom of the louder subs and increases their distortion

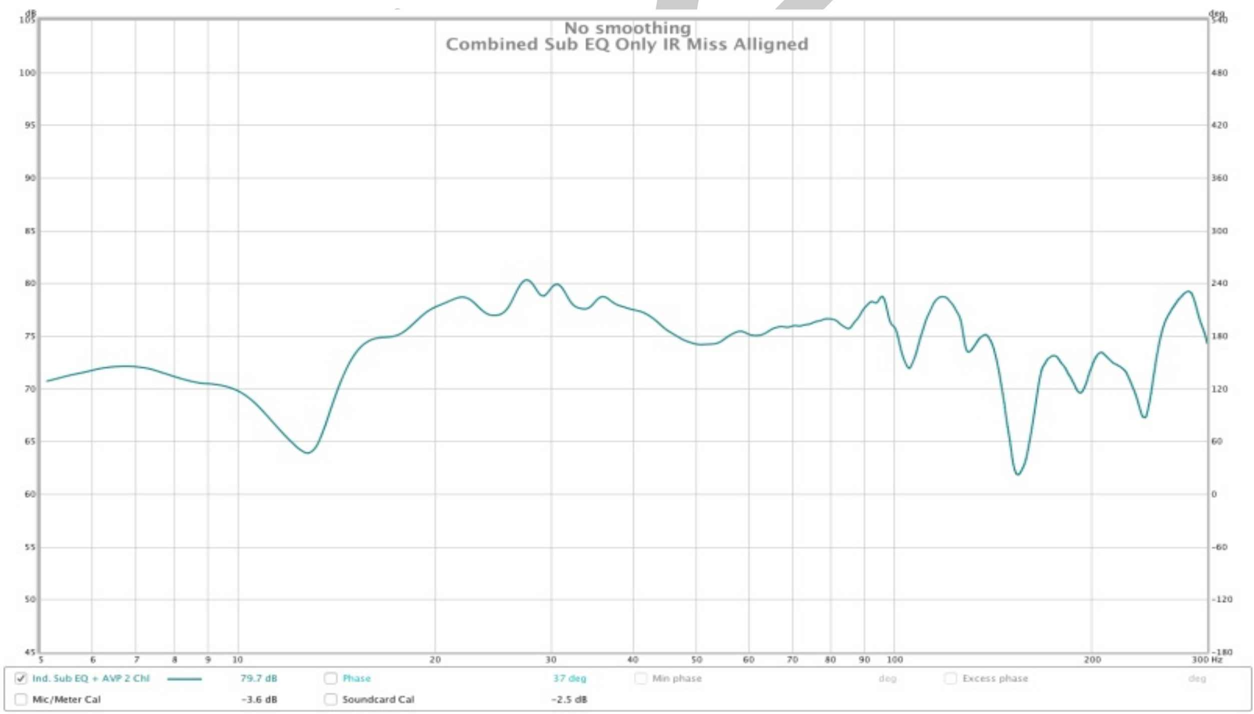
Point 1 above brings up a question:

a) EQ as two pairs
b) EQ as one set of four

The **final EQ** must always be *all* subs at the *same time,* as all subs will interact with the room's acoustics and each other at the same time. These interactions are complex, so trying to EQ individual subs, or pairs of subs, never takes into account the rooms acoustical interactions when all subs are driven simultaneously. This approach was validated numerous times having tried both approaches, see typical graphs below.

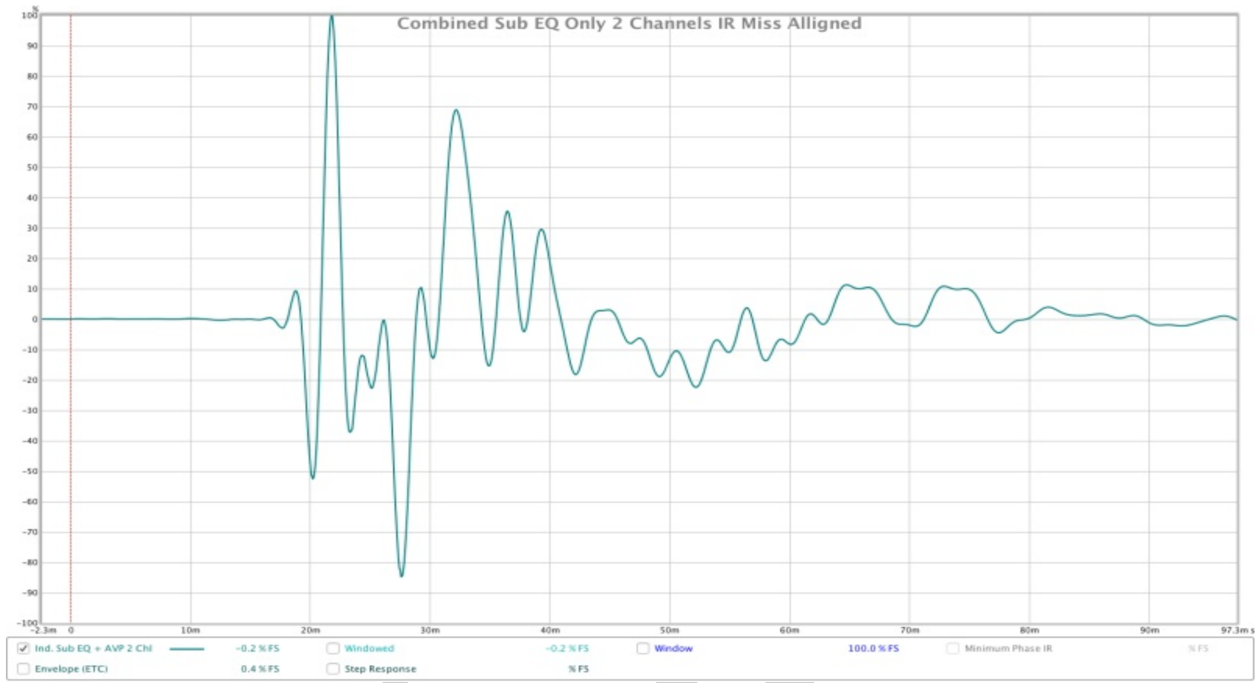


12. Two Individual EQ'd Channel Pairs Summed - IR aligned – Audyssey Sub EQ Only



12A. Two Individual EQ'd Channel Pairs Summed - IR miss-aligned – Audyssey Sub EQ Only

Simply adding two independently equalized pairs, even if time aligned, did little to help with the LF frequency response, it still rolls off at 15HZ as governed by the PB12NSD's response. Moving the IR alignment (relative time delays) of the two pairs of subs to get the flat frequency response shown above created a very poor combined impulse responses, see Graphs 11A & 12B, and made the bass sound unnatural and soft.



12B. Combined Impulse Response of Two Individual Channels. Miss-aligned in order to achieve the flatter frequency response shown in Graph 12A – Sub EQ Only

Graph 12A shows that there is more output below 15Hz, from the SB2000, but no other significant improvements over just two PB12NSD's, except the ability to create higher SPL's with lower distortion, neither of which I was looking for.

Note: Based upon the subs individual 3dB LF roll offs, Audyssey is clearly doing the right thing when equalizing dissimilar subs for the average user. It protects the apparently less capable sub from being overdriven but in doing so removes many performance benefits from the better sub.

While the above statement is generally true, careful manipulation of the subs combined performance can, as will be shown, overcome this problem. This statement assumes that the subs have the technical performance to support manipulation of their frequency response and the room's acoustic demands are not too excessive.

Listening Tests

I usually listened to music after every final run, having optimized the crossover by adjusting the sub delays (distance tweak) to obtain the flattest frequency response. This always used the recommended Audyssey crossover frequencies that never changed from 40Hz for all the 1038's, 40Hz for the rear and side 8040’s and 60Hz for the 8030 heights. The AVP sub levels were fairly consistent +-1.0dB, however, the optimized (distance tweak) sub distance setting(s) were “all over the place” based upon how I had equalized the subs.

Generally, no matter what I did, the bass, whilst reasonable for some equalization runs, was never very clean, tight or well integrated into the overall sound, and was generally thick in nature, often showing *both* a poor Impulse and Waterfall (decay) response.

At this point I needed a different approach to setup the subs and discarded the Audyssey Sub EQ for the subs initial alignment and/or just using the AVP. Clearly Audyssey was not going to achieve the integration and improvements I was seeking and I almost gave up believing that *dissimilar subs* could not be successfully integrated to the level I was seeking, with the hardware that I had available, and my inability to move the sub positions, *fortunately I was wrong*.

Final Approach

I concluded that:

1. As my 1038’s are used in many professional music control rooms and cutting suites *without subs*, I decided that I had no need to crossover to subs when listening to *most* music. Corner loading would easily extend the published -3db response of 33Hz down to 20Hz. (This extension must be dealt with carefully as these speakers are rated only to 30 Hz, below which they are heavily protected with LF filters as they are ported and designed to work in punishing professional environments.) Should I need to crossover to subs for handling movies, or extended bass in stereo/5.1 music mixes, I believed that correct impulse alignment with my subs would support it without distance tweaks – it did.
2. The subs could be setup and optimized to primarily handle the 0.1 LFE channel, keeping it nominally flat to 125Hz and relying on Audyssey to optimize just the small (8040/8030) satellite speaker’s crossover to the 0.1 LFE/sub channel.
3. I should revert back to using the SMS-1 for pre sub EQ as REW could generate the required frequency, cut/boast and Q settings required to **correctly** set it up.

The first issue was to set levels; this was achieved by setting each sub to 75dBA at the MLP using the averaging measurements made by my Audyssey Sub EQ. I trusted this system more than anything else as I was using Pro with its calibrated mic. These levels were then confirmed with REW and its calibrated mic, and as expected were all within +-1dB of each other.

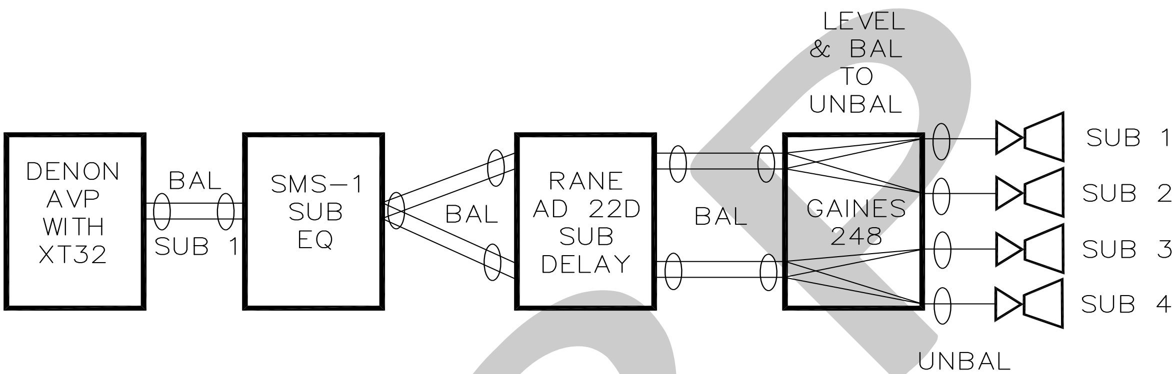
The earlier impulse responses showed:

1. The subs responses are different polarity’s
2. A time difference of approximately 3mS exists between the front and rear subs

The timing issue was resolved by adding a Rane AD22 to drive both the front and rear sub pairs. This allowed me to vary sub timing at will and exactly match the impulse responses (note later comments on

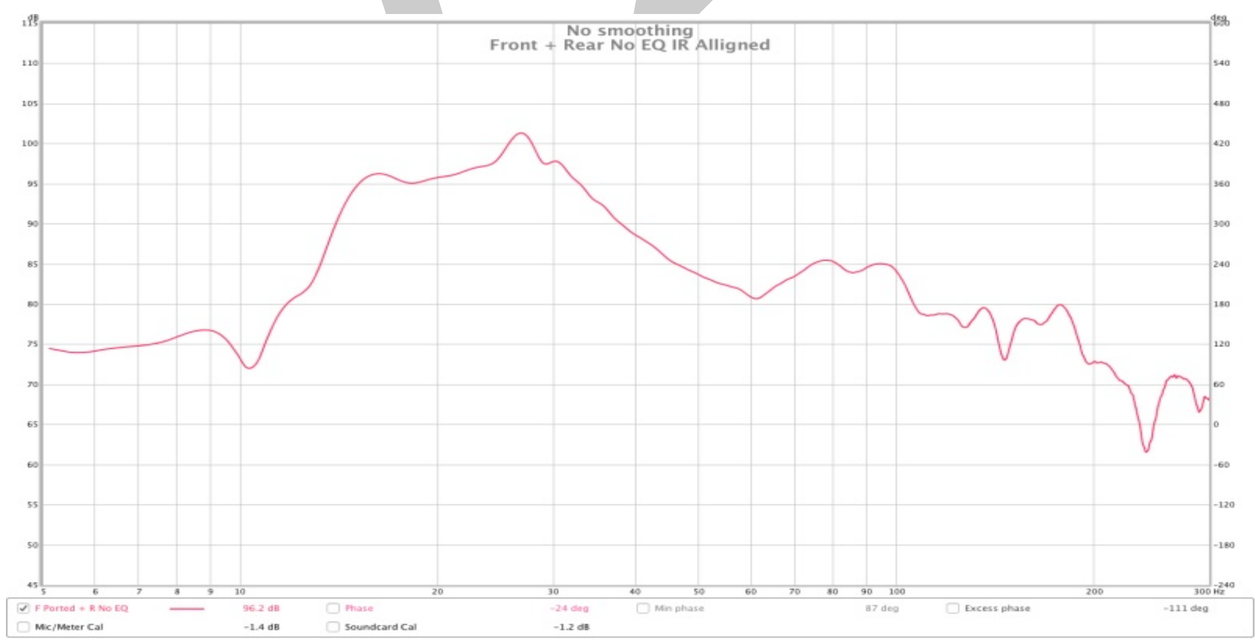
IR use). This delay is a result of the PB12's having analog processing and the SB2000's using a DSP and being closer to the MLP than the front subs.

A professional Gaines 248 was also added; this provided the required balanced to unbalanced conversion to support the subs and the required phase inversion. It also provided local level control of all four subs; and supporting a gain structure of unity to zero it could never be overloaded and clip. REW measurements of the frequency response of the Rane / Gaines hardware combination were ruler flat from 5Hz to 10KHz with distortion at full line level of less than 0.1%. The phase/group delay between 5Hz and 1KHz also being completely flat so would not adversely affect any group delays.

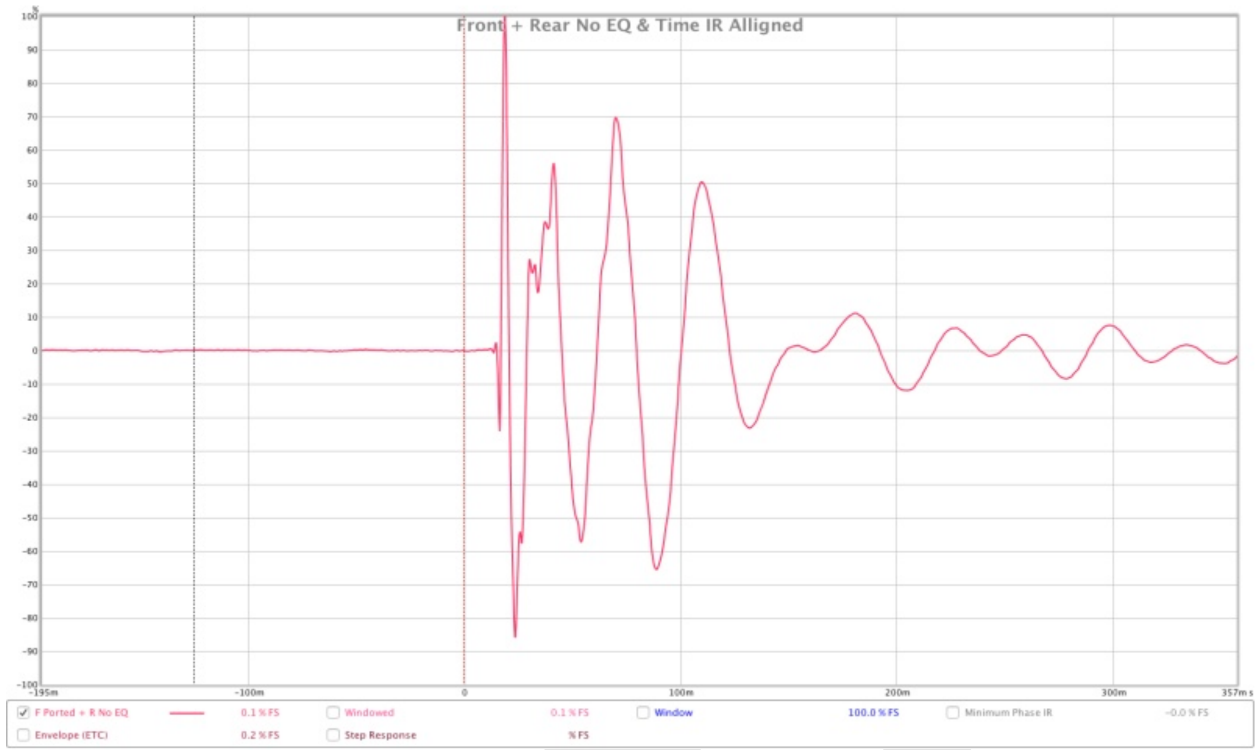


13. Final Sub Connectivity

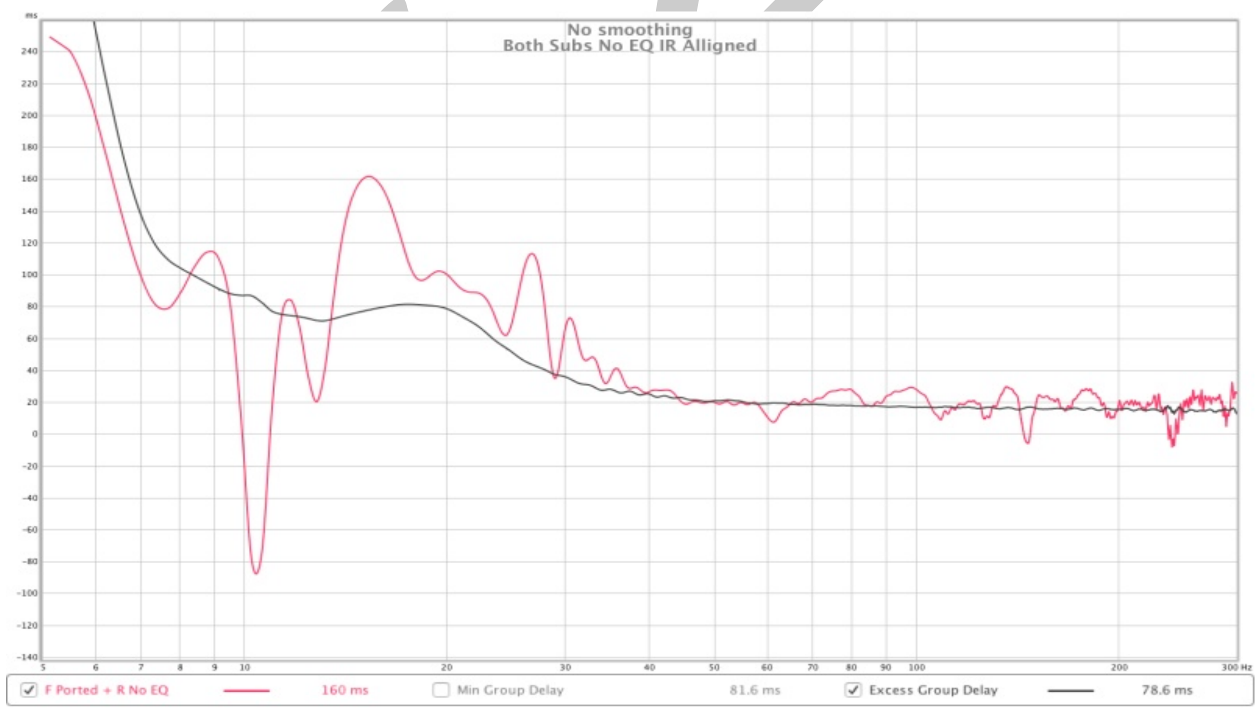
The following graph shows the combined IR aligned and *unequalized* responses for all four subs with the fronts in their final ported configuration:



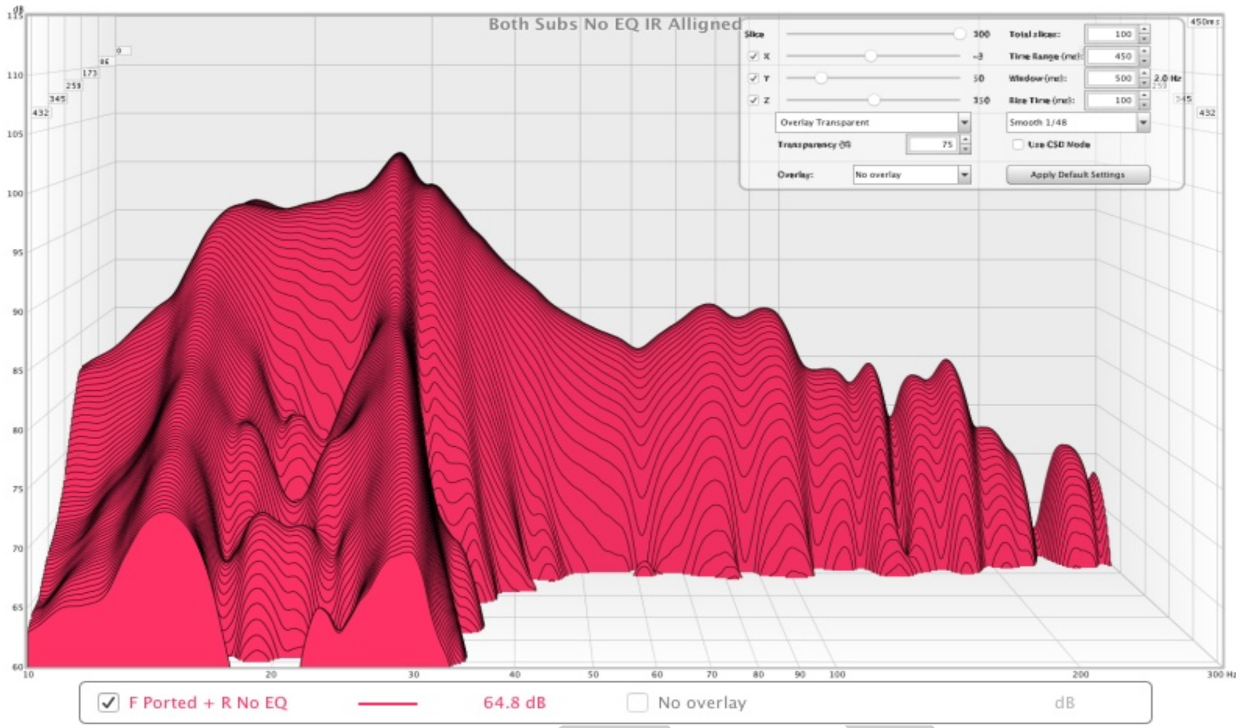
14. Sub Frequency Response, IR aligned with no EQ – front PB12's ported



14A. Sub Impulse Response, IR aligned with no EQ– front PB12's ported



14B. Sub Group Delay, IR aligned with no EQ – front PB12's ported



14C. Sub Waterfall, IR aligned with no EQ – front PB12's ported

Clearly not a very 'pretty' set of graphs!

In spite of the rooms significant LF absorption all the rooms' resonances can be clearly seen. In particular the ones at approximately 16Hz and 27Hz; both of which took me a long time to understand where they might be coming from as the room's longest dimension cannot support standing waves at those frequencies. The room's first mode is approximately 30.3Hz at 68 degees F; you can just see it in the graphs.

Construction Resonances

Panels can support flexing resonances just like rooms support standing wave resonances. As the room dimensions could not support either 16Hz or 27Hz, it was only possible to surmise what was happening based upon my measurements and observations.

Either the external box dimension of 20.5' was causing the standing wave at 27Hz as it could support it and/or the ceiling and wall panels were resonating at 27Hz and 16Hz.

(*The floor, due to its construction, weight and damping did not seem to have any obvious resonances*).

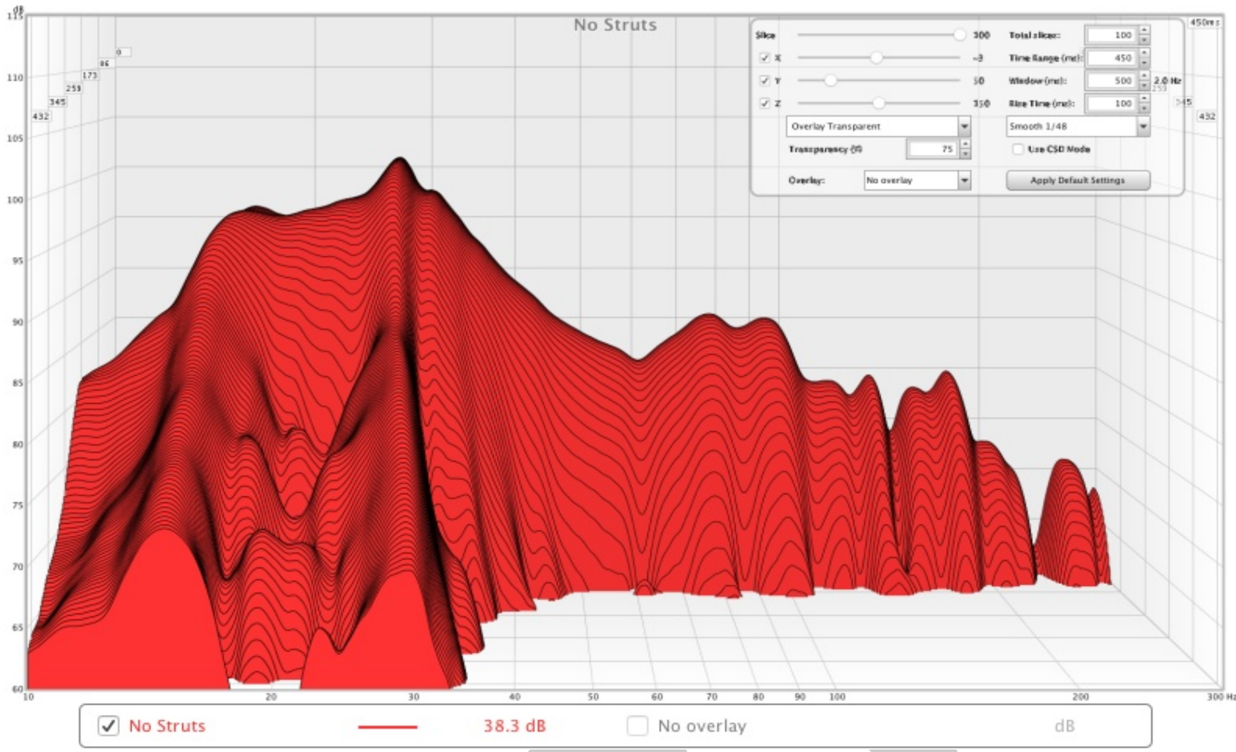
The room's construction is a *completely isolated* box within a box. The internal box is relatively flexible, using 2 layers of 5/8" drywall over 20" spaced studs, in order to get improved LF absorption. It also provides a different critical frequency to the outer wall that is on 16" studs also with two layers of 5/8" drywall. The external box walls form the house main structure and are massive, stiff and heavy in comparison to the inner box. At low frequencies the internal boxes' much lower mass and flexible walls, would be fairly transparent to LF energy. This could result in the external rigid box walls produced by the building supporting the 27Hz standing wave. This structural issue could not be changed. To make things worse the rooms' ceiling resonated at exactly 27Hz also and flexed significantly when driven at high levels (+85dB SPL). Was this the cause of the 27Hz resonance? No, read on.

The second poor decay is around 16Hz. Clearly, this is NOT an air based standing wave or an HVAC ducting resonance and was discovered to again be structural. Only the walls were found to resonate at this frequency. This issue could not be addressed with any changes to the rooms' construction.

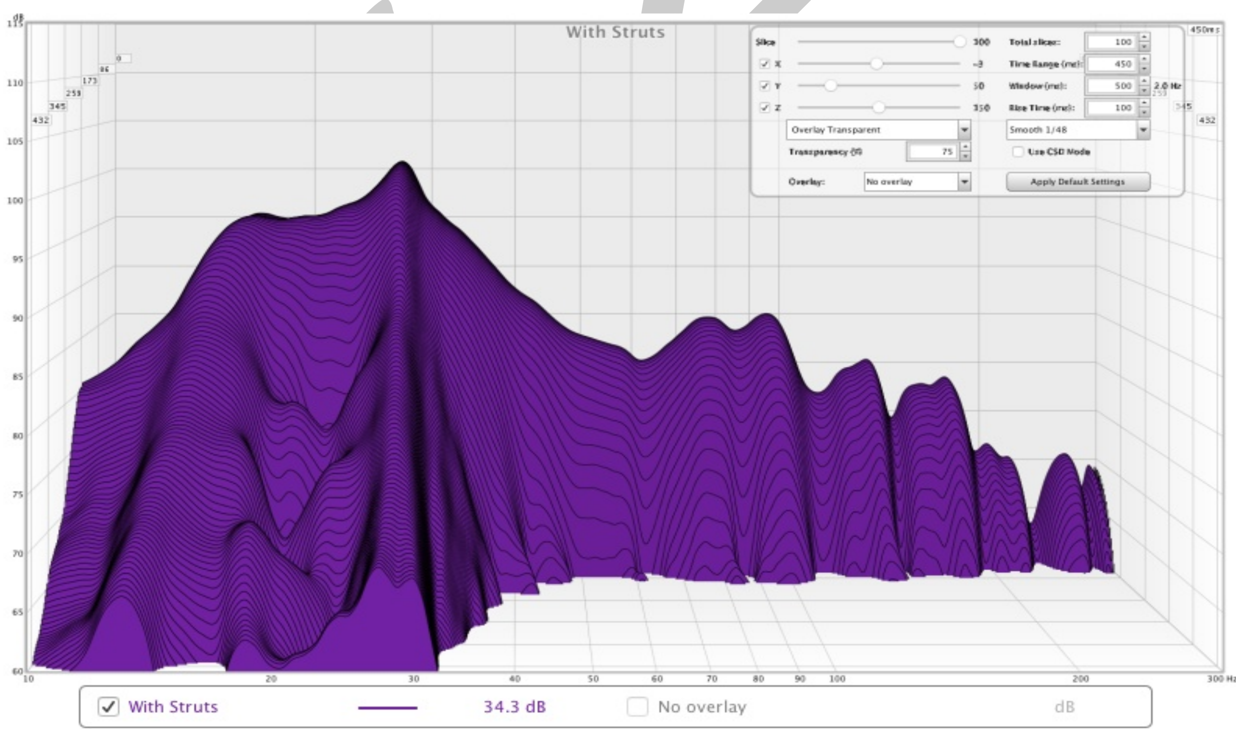
Well maybe it could have been reduced if had known about this potential problem earlier. The application of Green Glue between the two layers of drywall may have reduced this resonance.

In order to reduce the ceiling resonance, the ceiling joists were made much more rigid by adding the equivalent of an "A" frame to every other ceiling joist. (I should have used engineered I beams, like in the floor, but my architect said that the ceiling met all structural building codes (not acoustic!) using 6 inch joists.) This resulted in the following graphs:

15. Combined Sub Frequency response – with and without with ceiling joist "A" frames – no EQ



15A. Combined Sub Decay – without ceiling “A” frames – ported no EQ



15B. Combined Sub Decay – with ceiling “A” frames – ported no EQ

The 30.3 Hz room mode reduced slightly, probably due to less energy being put back into the room from the flexing ceiling. The 27Hz decay changed little as either the longest dimension of the ceiling needed to be braced or the standing wave was produced by the external box dimensions; neither of which I could do anything about. However, there was a significant improvement in the 16Hz decay time. Interestingly enough only the 27Hz resonance was ever detected in the ceiling with the 16Hz only being detected in the walls. The significant improvement of the decay time by 7dB after 400mS at 16Hz may be a function of less energy being coupled from the ceiling to the walls as now the ceiling didn't seem to flex much.

The disadvantage of stiffening the ceiling was that the decay time significantly increased by 8dB at 30Hz as it no longer absorbed very much room energy, but dropped an additional 9dB at 40Hz. This was probably because less energy was being put back into the room from the ceiling. The loss of performance at 30Hz was shown not to be a problem in later EQ and measurements.

15C. Decay Without A Frames. 30Hz decay 23dB, 40Hz decay 28dB both after 160mS.

15D. Decay With A Frames. 30Hz decay 15dB, 40Hz decay 37dB both after 160mS.

In desperation I tied my A/V rooms ceiling joist to the main 12" deep roof rafters using a series of 2" x 4" ties; now the ceiling couldn't flex in any direction. Well, it neither improved nor changed anything! I removed them, as I therefore concluded that it must be a standing wave caused by the external box dimensions, and their addition achieved nothing and reduced the room's isolation from the main house.

Attic and Crawl Spaces

The antic and crawl spaces above and below my room formed the external box dimensions, and were totally untreated. The space beneath the room had lots of ducting and air handling in it, but the attic space above the room was totally empty. After cutting a hole into the wall in order to gain access to the attic I discovered that:

1. It rang like a church bell due to the flutter echo between the parallel end walls on the longest dimension.
2. After testing I found that it supported a 27Hz standing wave.

Point 2 also meant that the much smaller crawl space below the room *might* also support a 27Hz standing wave. This was never confirmed, but it didn't support flutter echo due to all the HVAC equipment.

I hoped that as the ceiling resonated at 27Hz that this maybe because the space above it supported a 27Hz standing wave and was being acoustically coupled to it. I therefore turned the attic into a huge LF trap by installing 3" thick hanging absorbers for the entire width of the space from every roof joist.

Well, that turned the space into an anechoic chamber, and after measuring it a second time it had no apparent 27Hz standing wave and obviously no flutter echo. I also hung the same absorbers from the under floor joist over the largest area possible in the crawl space, but this was only about 33% of the area, due to the need to access all the HVAC equipment. I also lined all the crawl space walls with 3" of Roxsul, just in case!

Well you might have guessed it, but the ceiling still resonated at 27Hz and the peak at 27Hz didn't change at all. (I was becoming a little frustrated at this point in time)

I now realized that any further improvement in the decay of these frequencies was going to be a function of the subs EQ.

At least the ceiling hung projector no longer bounced around on deep loud bass ☺.

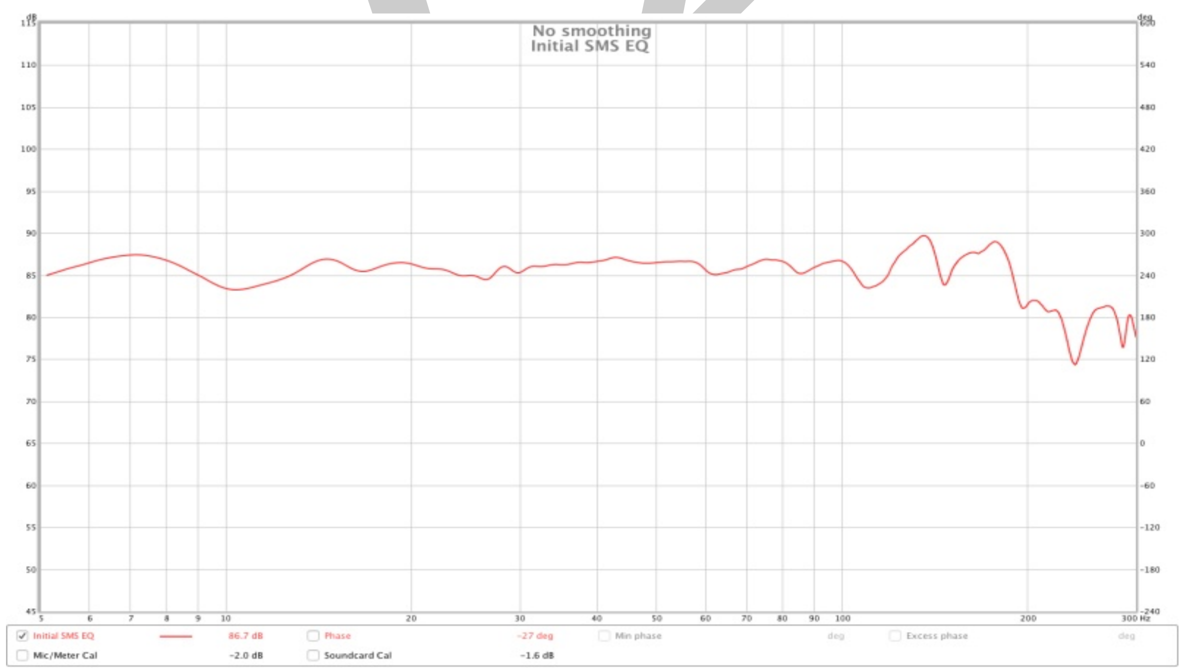
So onto the room's equalization.

Initial Sub EQ

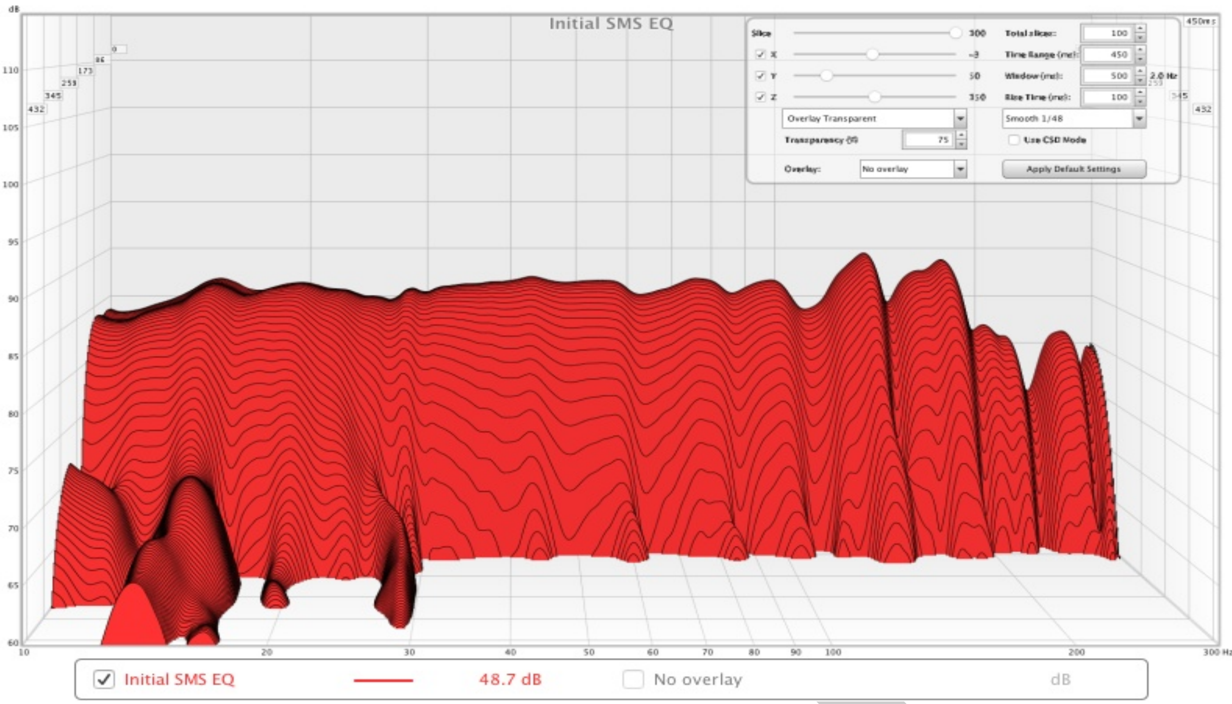
With the subs levels and impulse response timings matched, the sub system was equalized as a whole. REW offers a terrific program called EQ that I used to achieve this. The program analyzes the frequency response of the room, determines the resonant frequencies (poles), and to put it simply, calculates the filters matching zeroes in order to cancel the pole (room) resonances. This reduces the effects of room resonances, flattening the rooms' frequency response and improves decay times. The program also allows you to move the reference level, thereby allowing me to reduce the mid band SPL so that the overall response became almost ruler flat.

***A word of caution**. While pushing the mid band energy down using EQ, provides the desired extended flat response, you will now potentially be trying to drive subs at frequencies below their designed cut off. Also, in order to get the overall sub SPL levels back up to where you need them, the required line levels may exceed what the subs are designed to handle. In my case, I only have an 1800cuft **SEALED** room, so with this many subs I did not need to excessively drive them at low frequencies in order to get the desired output and associated room SPL's.*

After measuring the room's unequalised response using REW, you select your EQ device (an SMS-1 in my case) and set your desired final response level, roll offs etc. and the program determines the frequencies, cut/ boost and Q required to obtain the flattest frequency response and level. The process has the real plus that it specifically targets your room resonances. It is also amazingly accurate; the predicted frequency responses and decays were always virtually identical to what I measured and could easily be tweaked to improve any discrepancies. Once the EQ values were applied to the SMS-1 it created the following responses:

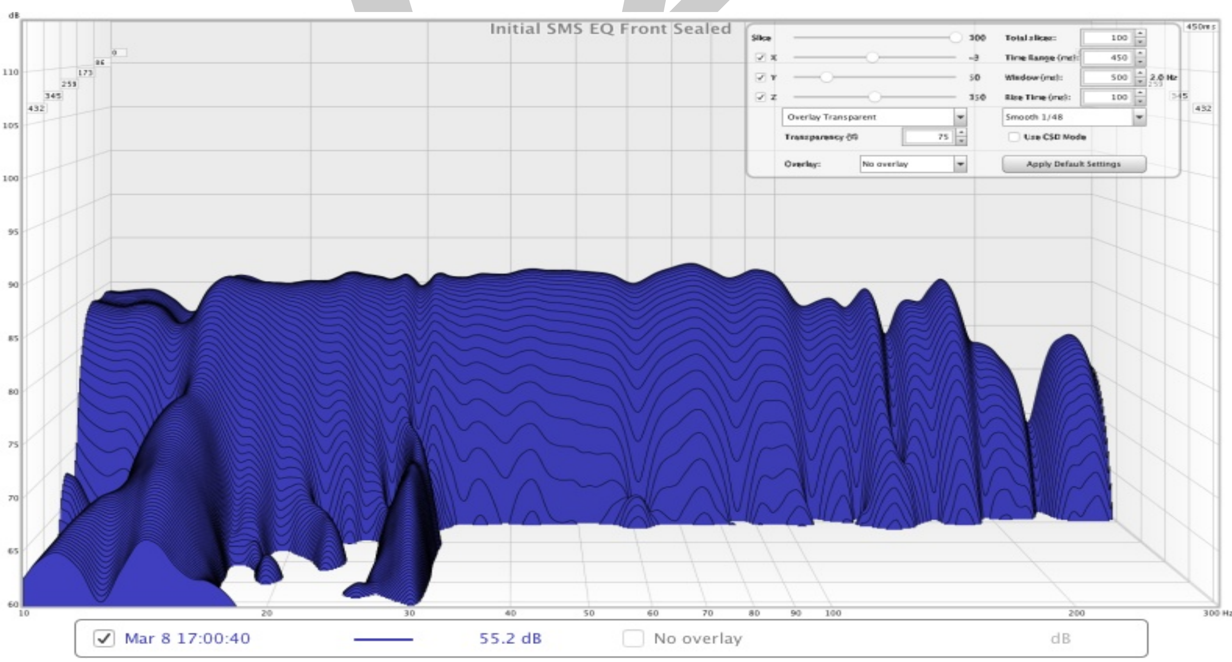


16. Initial Sub Frequency Response – SMS1 only – Is this flat enough for you?



16A. Initial Sub Waterfall – SMS1 only. SB12's ported. A huge improvement in decay times.

Several iterations of this EQ process were executed to see if sealing the front subs and creating a group delay closer to the SB2000's improved things. Generally, the sealed approach resulted in very similar frequency responses once equalized but resulted in worse decays than ported. See a typical waterfall below:

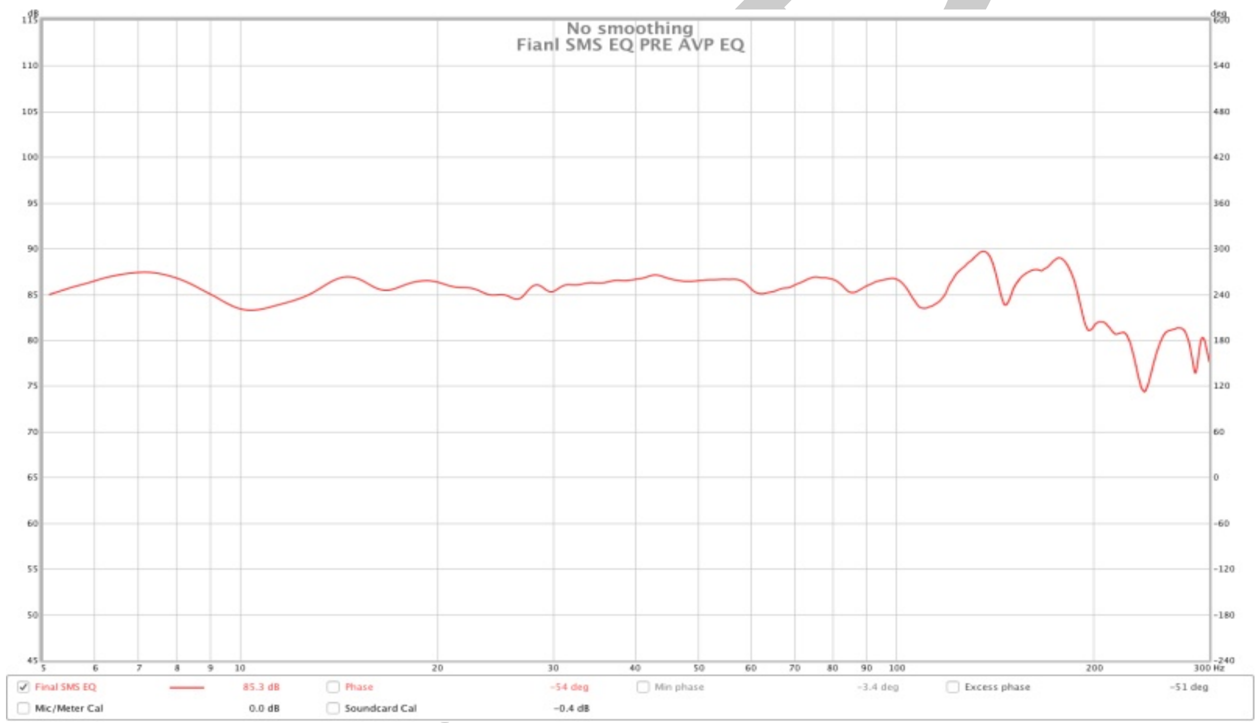


16B. Typical Front Subs Sealed Waterfall – SMS-1 only. SB12's sealed.

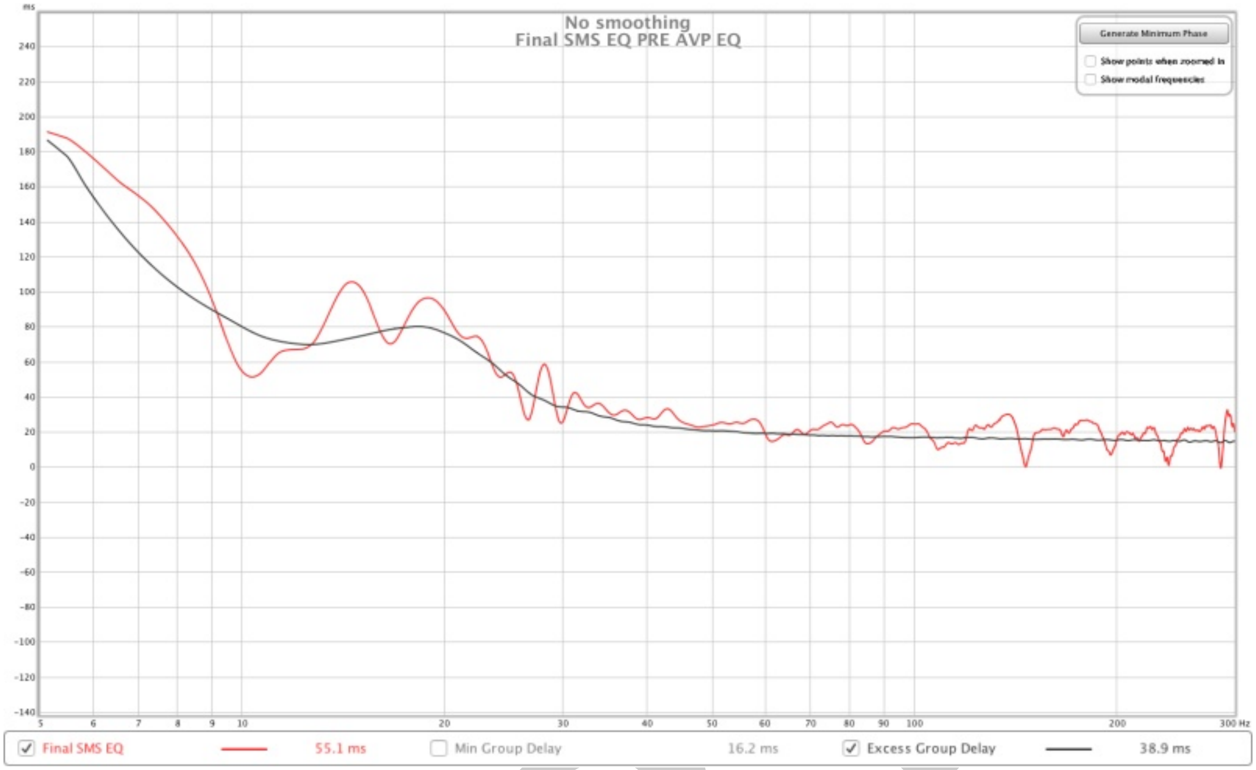
Note the increased decay times at 30Hz and below 16Hz. I suspect the waterfall shown in graph 16B was a result of the front subs lower LF energy output and/or change in group delays not cancelling the rear SB2000's.

No matter what approach was used REW always created the ideal set of coefficients and I believe that if the SMS-1 had more than 8 bands, with EQ below 15Hz, the response would have been better optimized at both 16Hz and 27Hz. I knew from previous experience with Audyssey XT32, that frequency variations above 100Hz would normally be readily corrected when the AVP was run to EQ the satellites, so any level changes above 100Hz were ignored for the SMS-1 EQ routine and all 8 bands were limited to 15Hz to 90Hz.

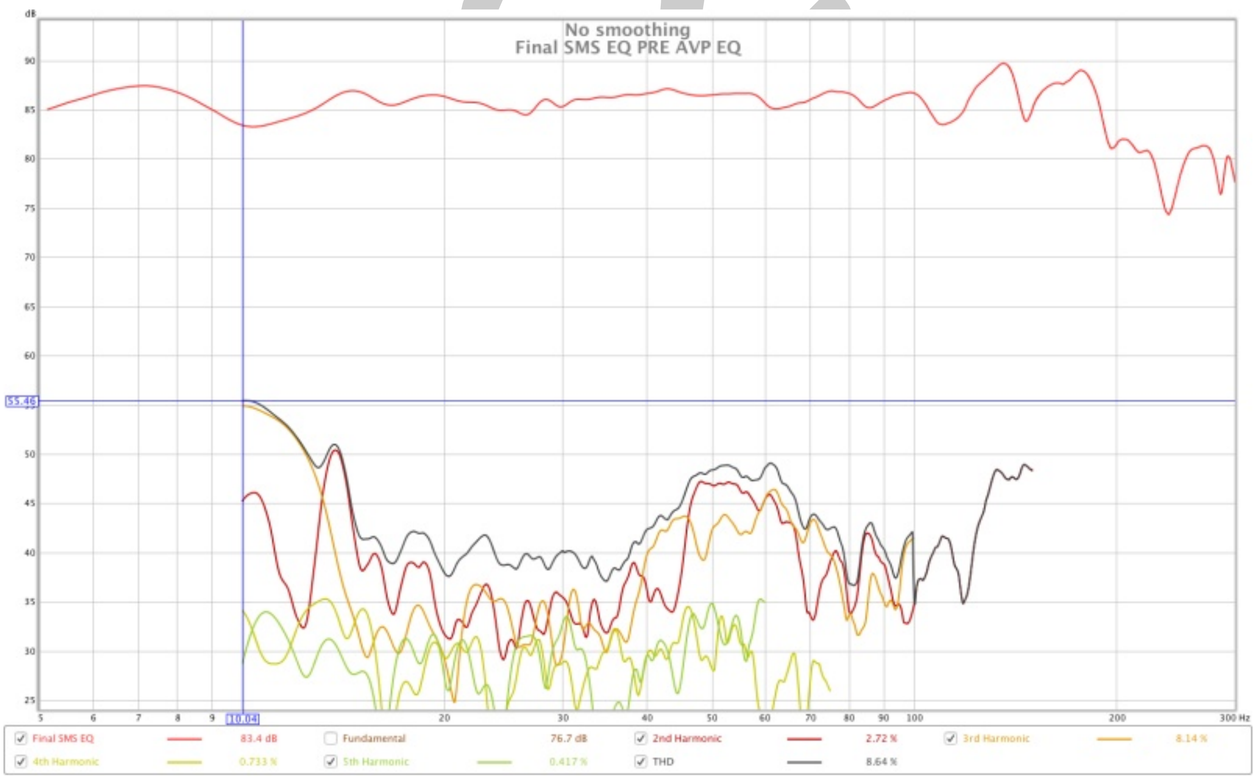
The following are the final SMS-1 equalized sub responses prior to EQ by Audyssey in the AVP:



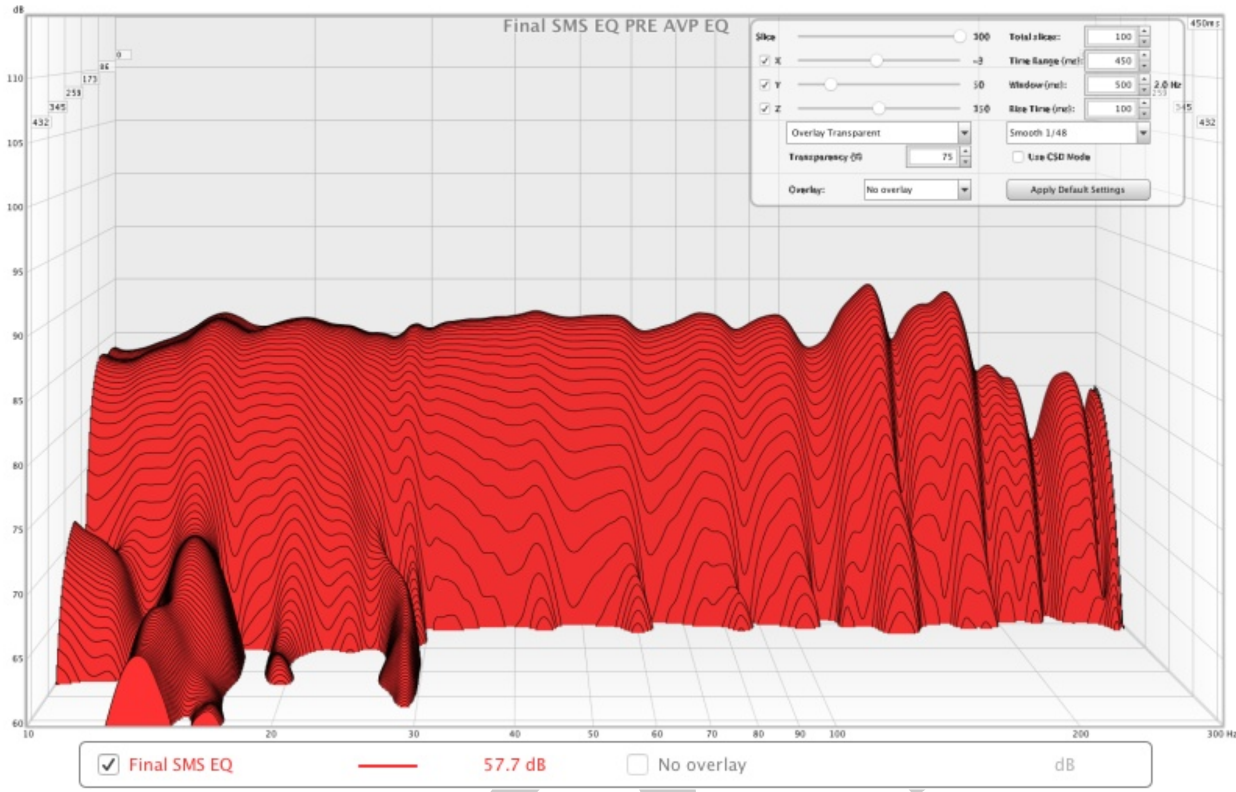
17. Sub Final Frequency Response – SMS-1 only, front subs ported



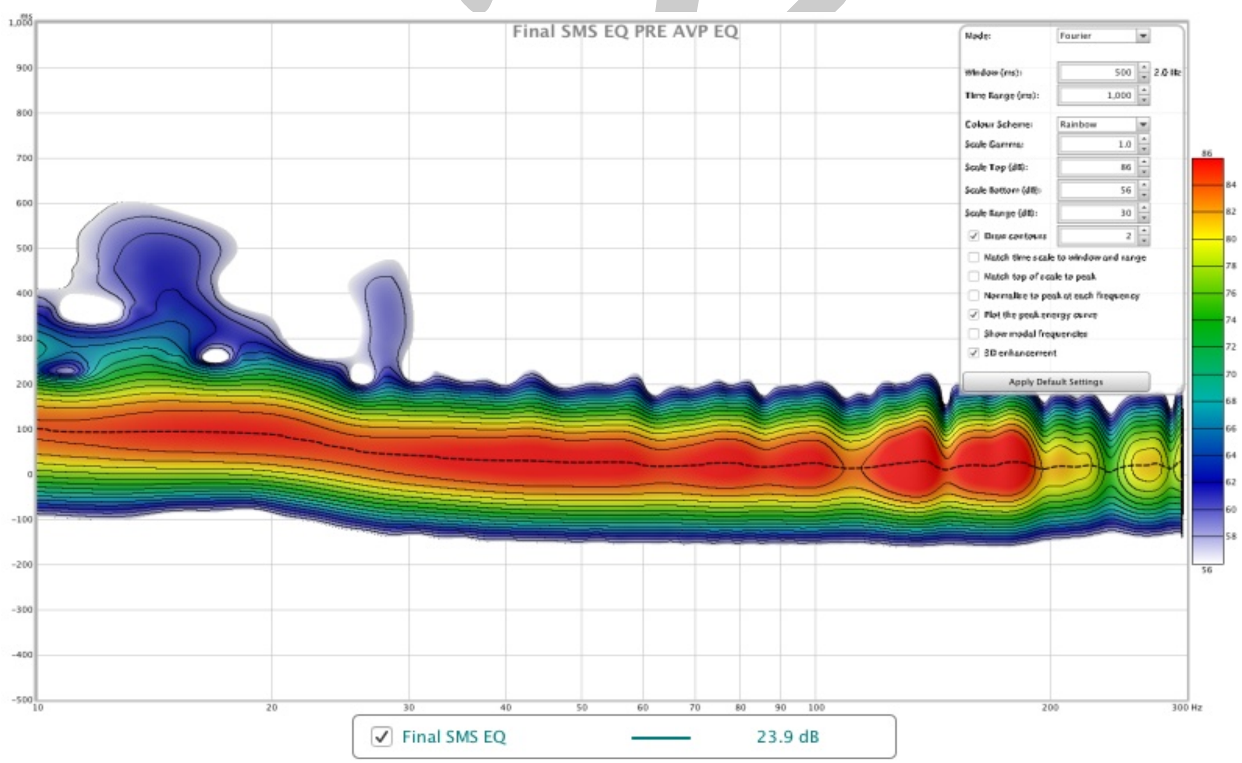
17A. Sub Final Group Delay – SMS-1 only, front subs ported.



17B. Sub Final Distortion



17C. Sub Final Waterfall



17D. Sub Final Spectrograph

The above graphs 17A through 17D clearly show the rooms remaining resonances at 16Hz and 27Hz. Both are now at an acceptable level (better than -20dB in the first 200mS), especially allowing for the rising group delay at frequencies below 30Hz.

At this point I considered the subs correctly equalized and optimized to the rooms acoustics and it was time to run the AVP Audyssey XT32 in order to integrate all the satellite speakers.

Final Room EQ with AVP

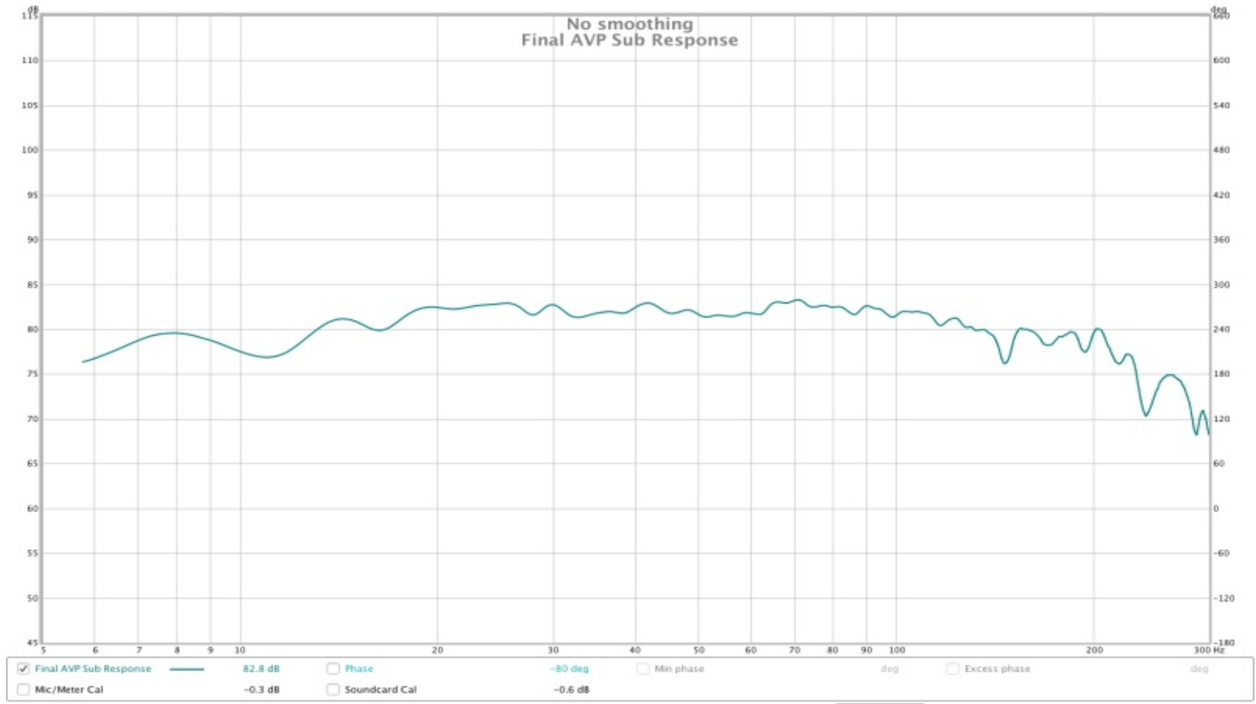
With the subs pre-equalized, Audyssey XT32 in the AVP was run using Pro. Unfortunately, you have no choice but to let Audyssey EQ the subs as part of its routine, something that I felt may adversely impact the decays. As can be seen in graph set 18 below Audyssey did three things to the sub response:

1. Audyssey in conjunction with the AVP electronics created some additional roll-off below 15Hz
2. It flattened out the subs frequency response
3. It improved all the decays. At LF this is just a function of the additional LF roll-off.

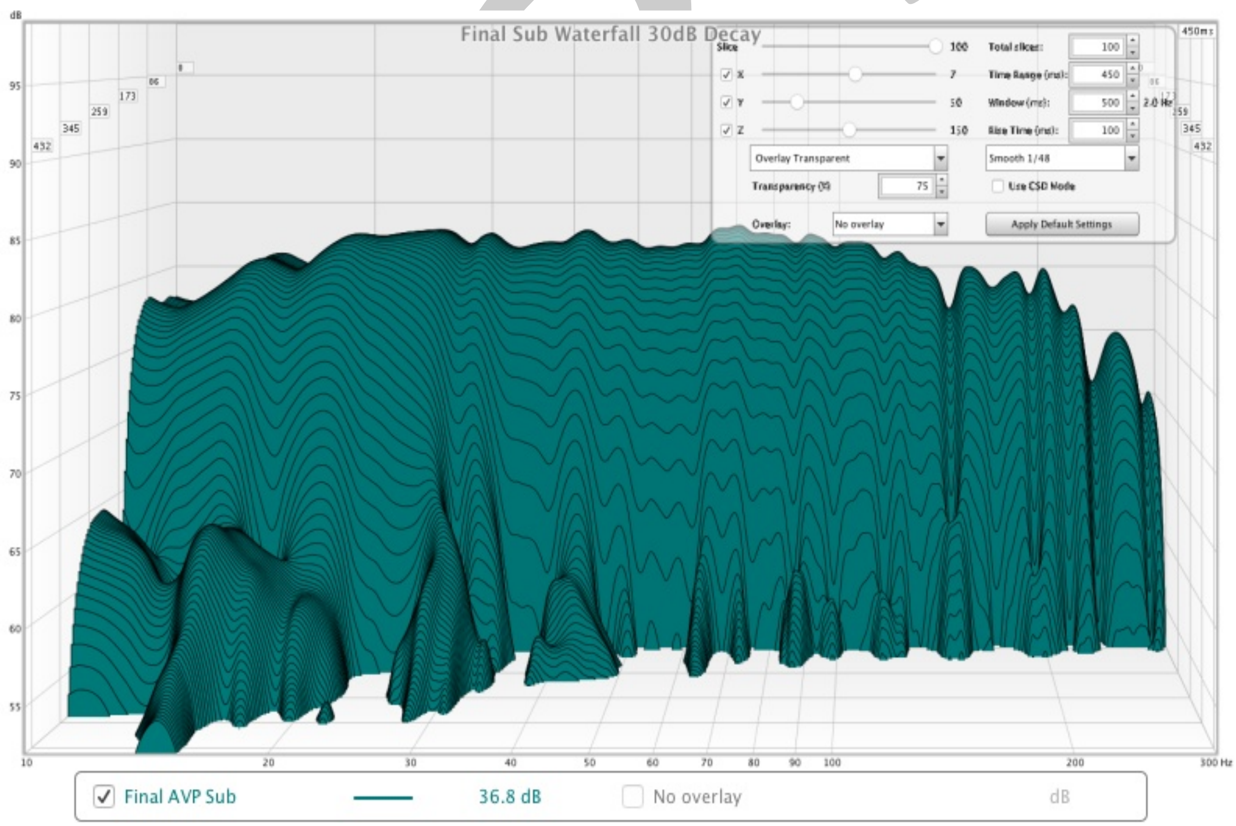
As Pro is used for my AVP EQ I elected to leave L, C, R, LR and RR at large for the 1038's. The smaller rear 8040 surrounds and 8030 heights were set for a 40Hz and 60Hz crossovers respectively, as recommended by Pro. The five main satellites were set to large as I did not want Audyssey to impose its EQ shaping on the equalized responses, something that it does when it optimizes for the selected sub crossover frequencies. The five mains are matched Genelec 1038's that each have a 15" bass unit driven by a 400 watt amplifier, so they did not need any help down to 30Hz. Crossover selection could always be made at a later time if required.

The low pass filter, in the AVP, for the 0.1 LFE channel was deliberately set to 200Hz in order to ensure that the channels response was flat to 125Hz, which is where the 0.1 channel "brick wall" filter associated with movies is active. (There is now some debate as to whether this filter is actually used by the film industry in any consistent manner).

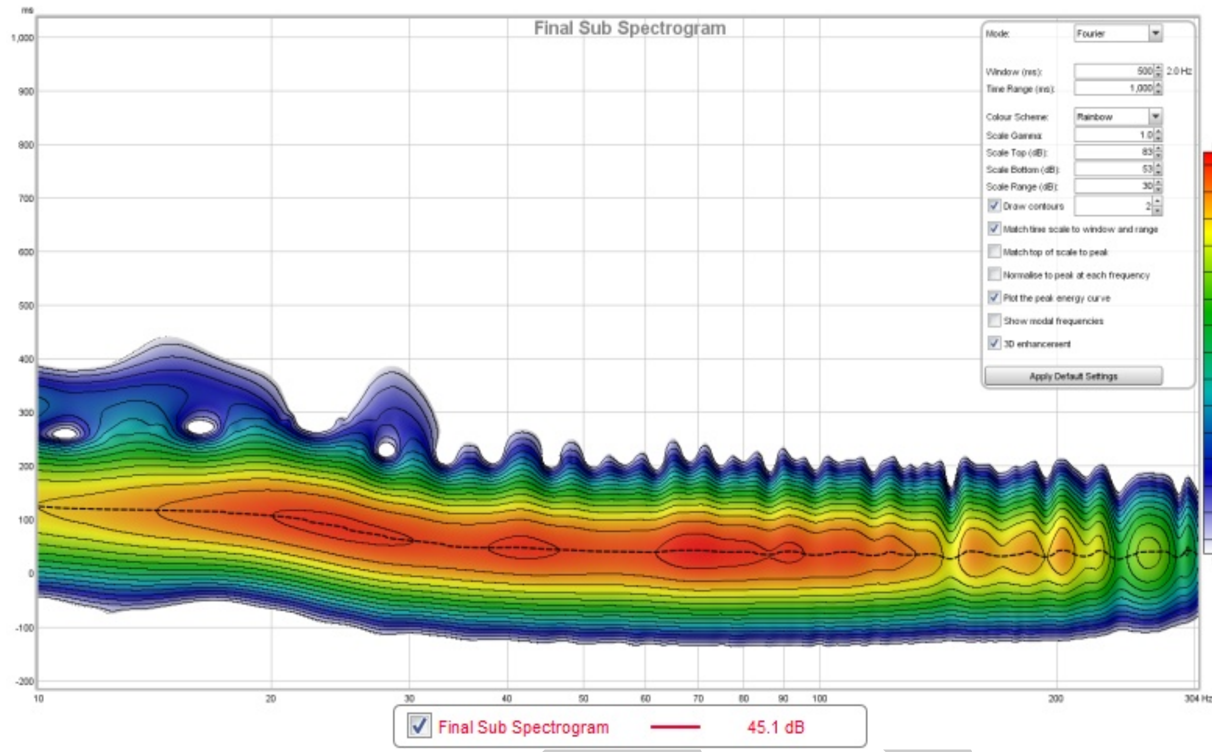
The final AVP+SMS sub responses are shown below:



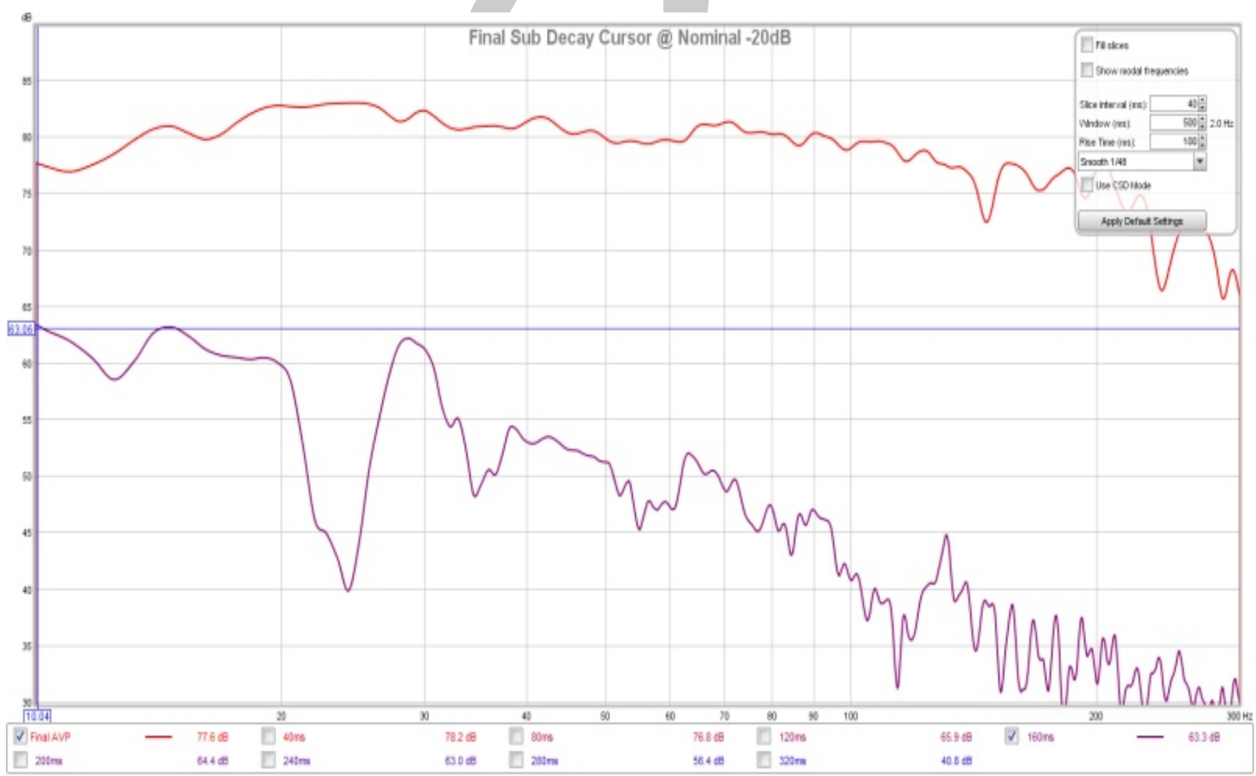
18. Final Sub Frequency Response with AVP EQ



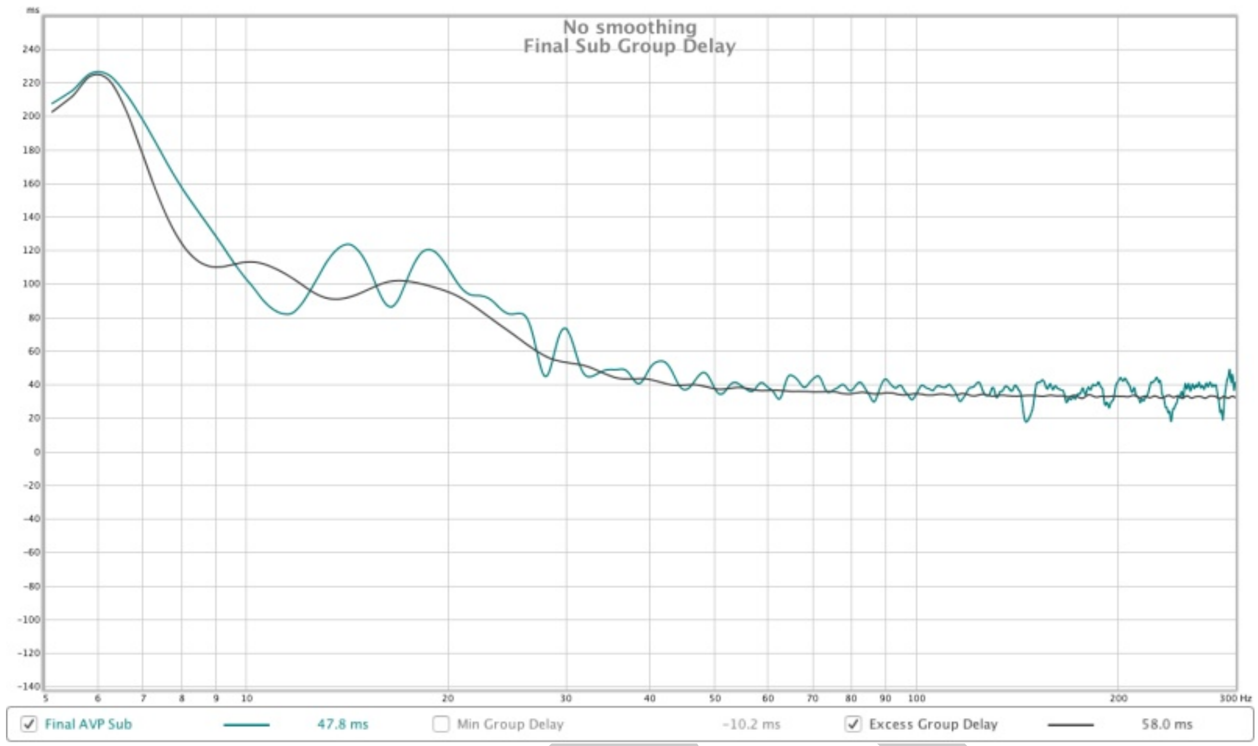
18A. Final Sub Waterfall Response with AVP EQ



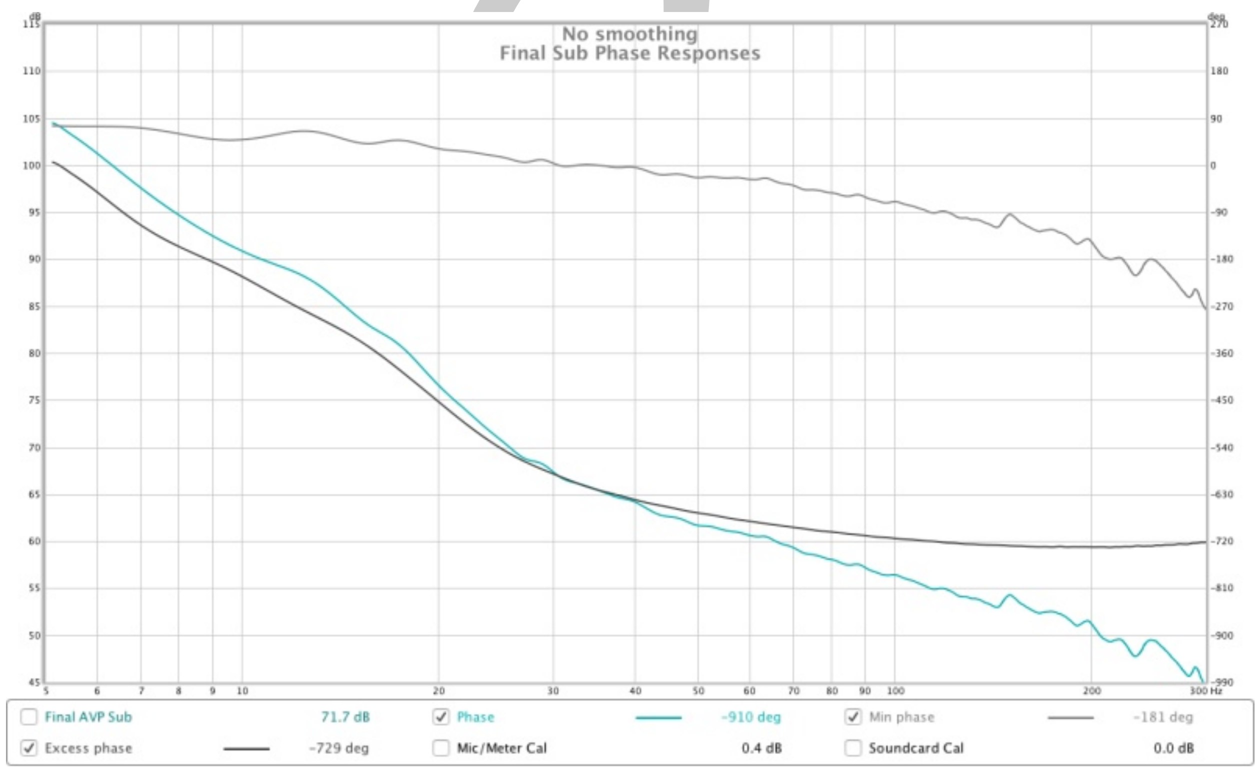
18B. Final Sub Spectrograph with AVP EQ



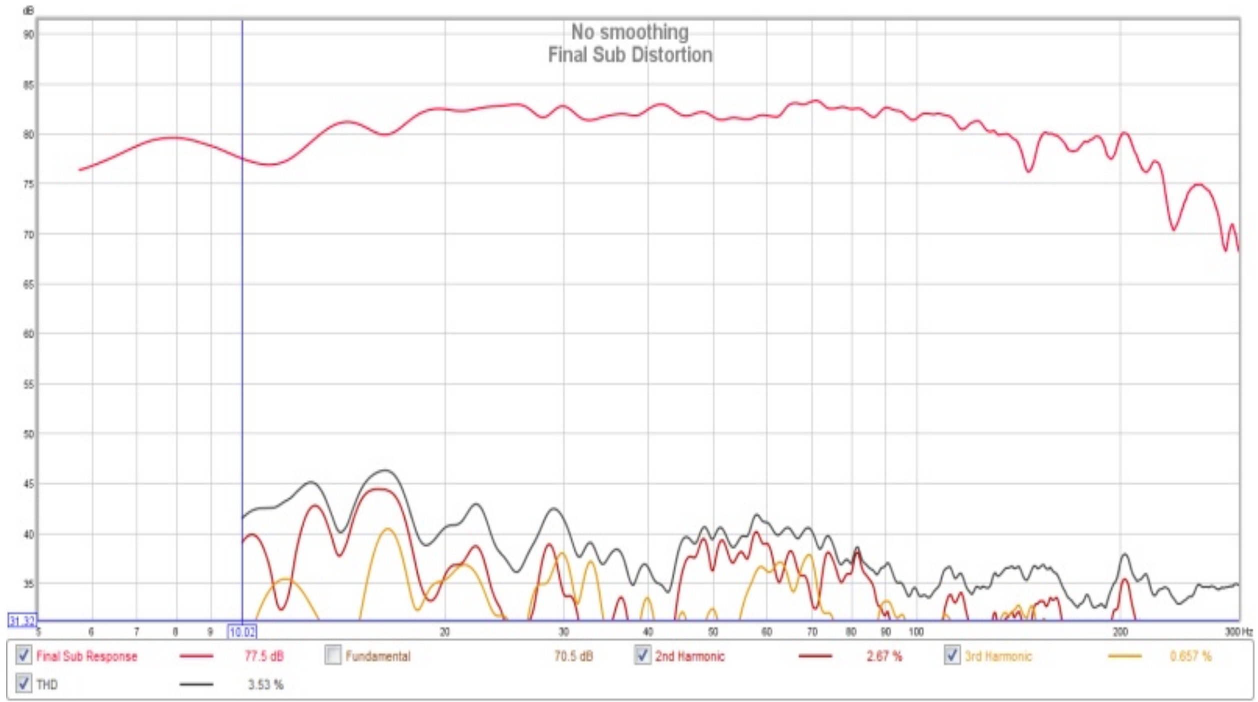
18C. Final Sub Decay with AVP EQ. The ideal decay time is -20dB after 160mS at all reproducible sub frequencies. Pretty close all the way down to about 13Hz.



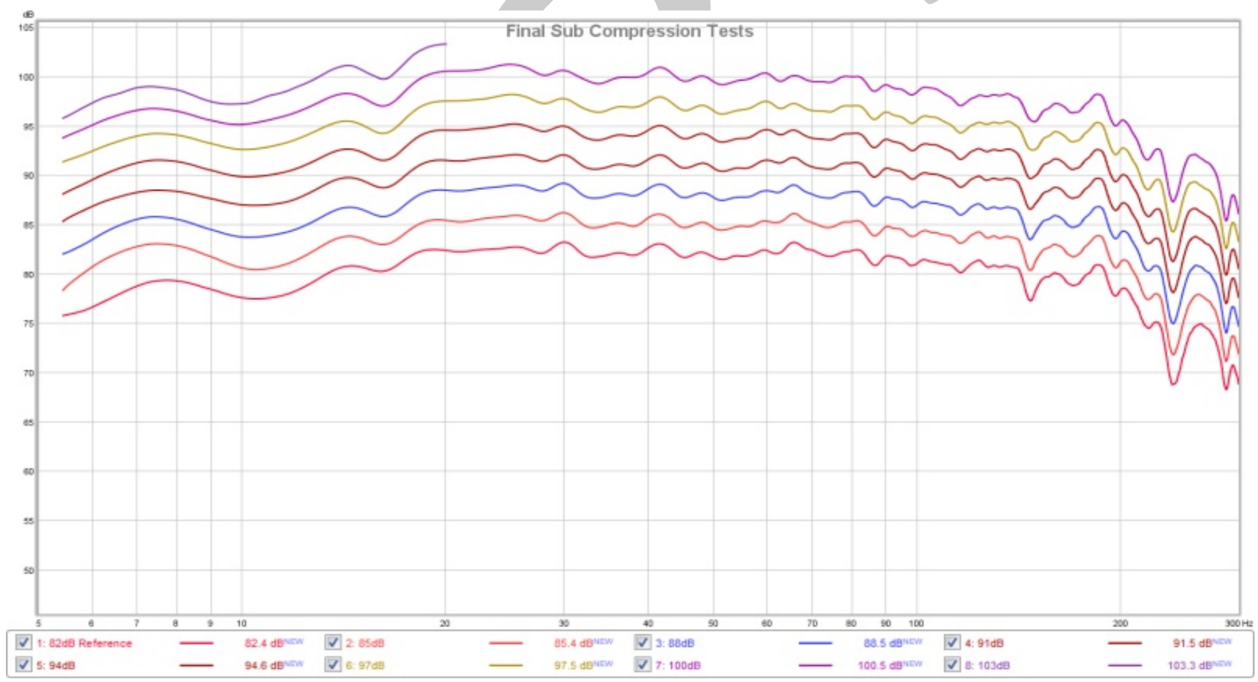
18D. Sub Group Delay. Meets the better than 1.5X period time all the way down to 10Hz.



18E. Sub Phase Responses

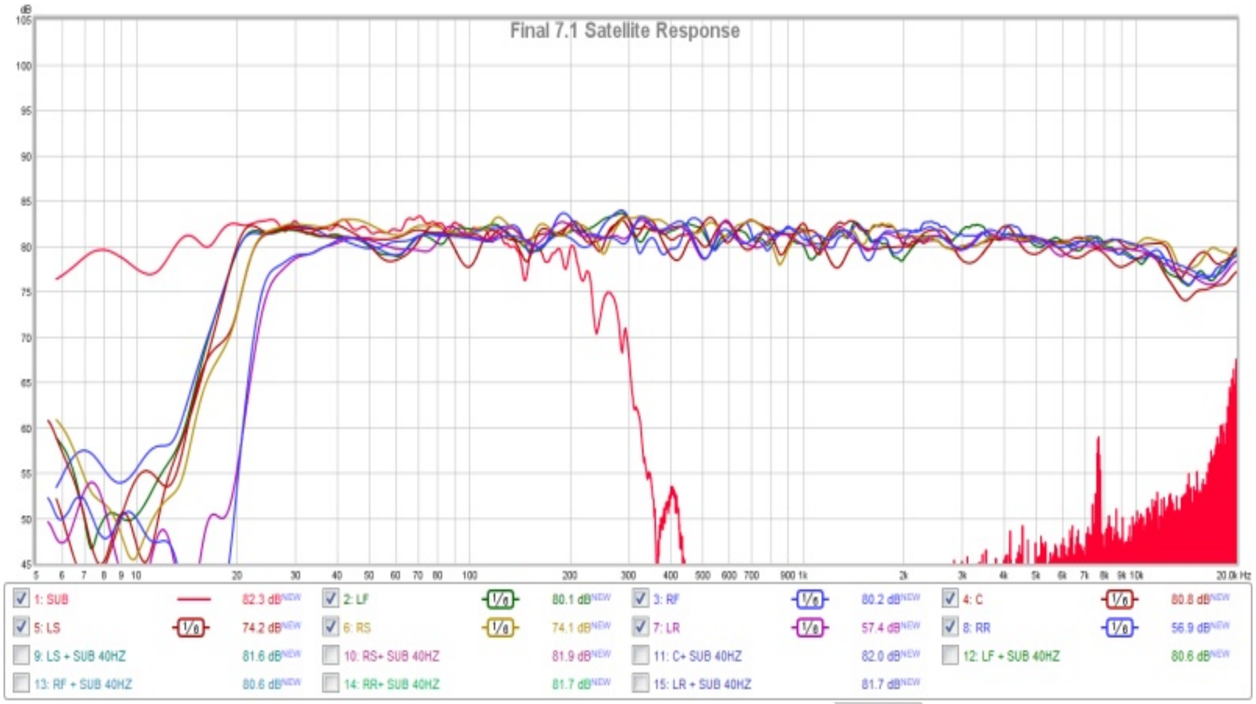


18F. Sub Distortion – nothing of consequence.



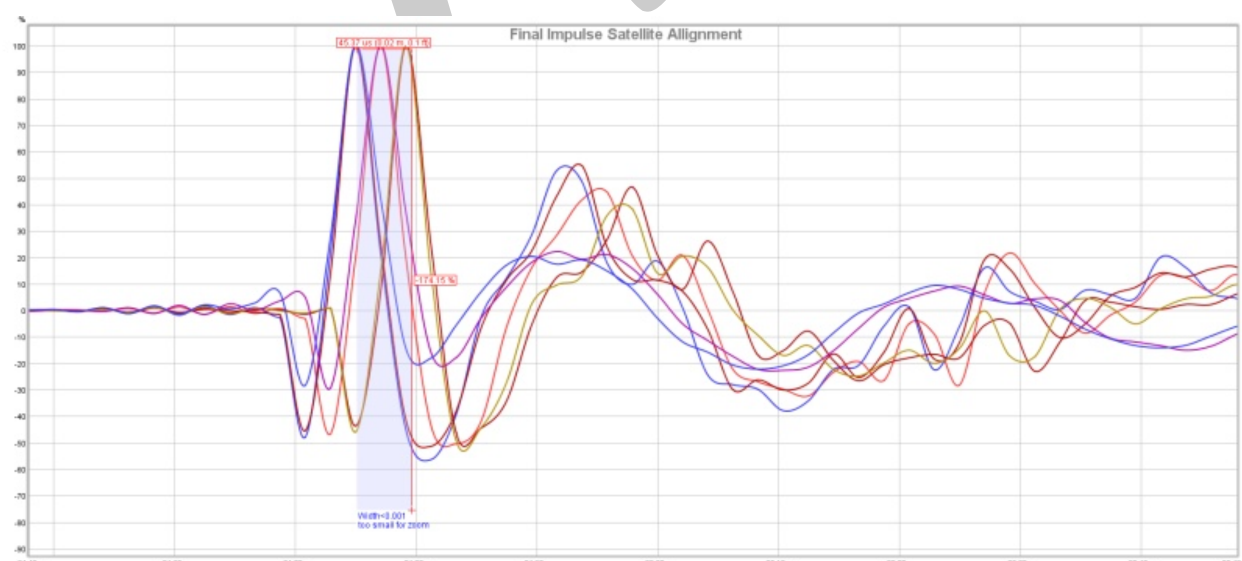
18G. Sub Compression – Absolutely none seen.

I had to terminate the 103dB run at 20Hz as my room (not the subs) was doing very uncomfortable things. And yes - at 100dB there is significant distortion below 12Hz – but I cannot hear it!



18H. Final Satellite Frequency Responses after AVP Audyssey EQ– The red HF noise is a result of a full BW sub sweep and can be ignored. (The uptick in the HF frequency responses above 15kHz was a sampling error and is not relevant.)

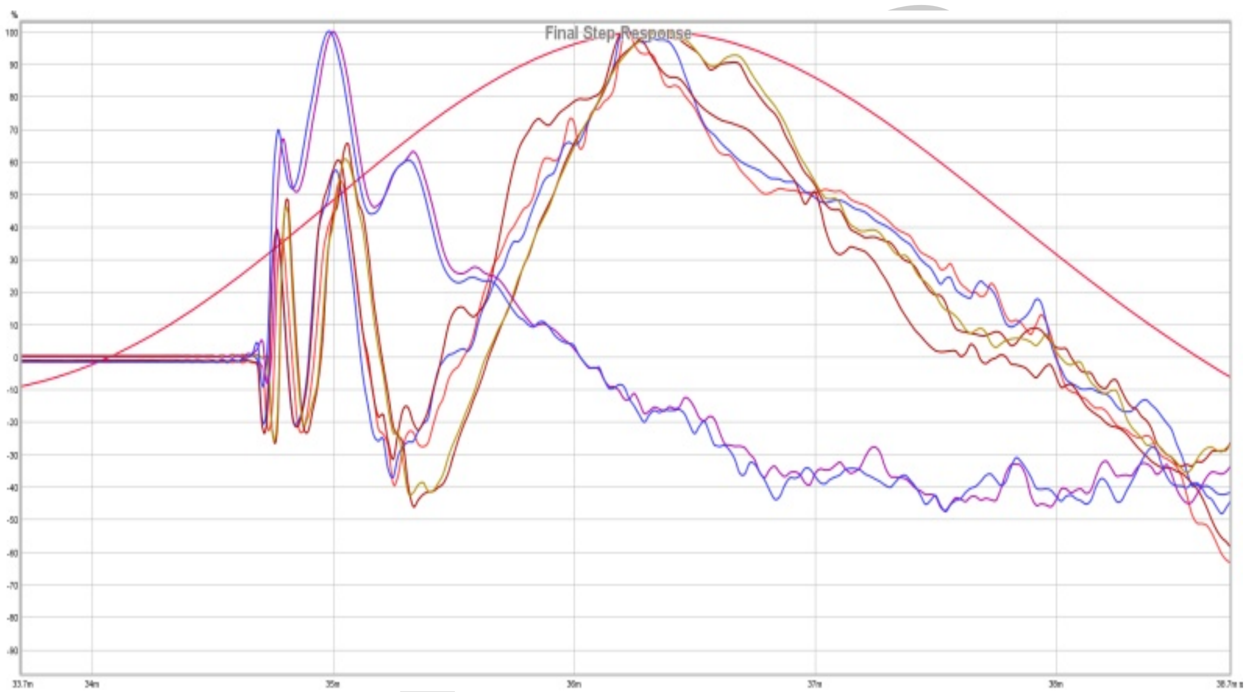
Once the satellites were equalized the impulse responses of all speakers at the MLP were adjusted using the AVP distance settings in order to be co-incident. The Audyssey distances were close, but not close enough. The AVP can only adjust in 0.1foot increments and allowing for imperfect microphone and speaker placement all satellites were adjusted to be within +-0.1 feet.



18I. Seven Satellite Speaker Impulse Responses. Aligned within 45 microseconds or better than 0.1 feet.

Sub Timing Alignment

The final sub timing alignment was not accomplished using the above technique. For this the subs and satellites *Step Response* was used. Without going into great technical detail, a step response graph shows the impulse response of all *speaker chassis* that make up the speaker, simultaneously. The normal impulse response cannot do this, as it is heavily weighted towards the highest frequencies and therefore only the HF unit. Simplistically, the ideal impulse has no width therefore has no LF energy. The step response is literally a step, so contains a lot of HF and LF energy and can therefore be used to show the impulse response of lower frequency mid range and bass units. Such a signal cannot be used in reality due to its DC component but can be *created mathematically* from the REW data.



18J. Step Response for the Satellite (5x1038 & 2x8040) & Four combined Subs

The graph shows the five 1038's, the two surround 8040's and subs combined step responses. The first seven peaks are the tweeter impulse responses, the second seven peaks at 35mS are the mid-range impulse responses, and the third set of impulses at 36.25mS belong to the five 1038's bass units and the subs. Note how all five 1038 satellite speaker HF, middle and sub impulse responses are in alignment, even the HF and mid/sub for the two 8040 rears (purple & blue). (*Being simulated, the front heights cannot be measured, as there is no access to them via the AVP. The secondary 8040 movie surrounds will be addressed later*).

The AVP sub delay was used to align the sub step impulse (red) to the 1038's bass speakers step impulse at 36.25mS. As all subs have very similar bandwidths (and group delay/phase responses) it is therefore possible to directly compare these impulse timings. Using impulse measurements to align speakers with different bandwidths won't work, because as stated earlier, the impulse response is heavily dependent upon the amount of HF energy present in the signal. Filtering out a given bandwidth is not a good way to do impulse comparisons either, as you are now looking at the filters performance too.

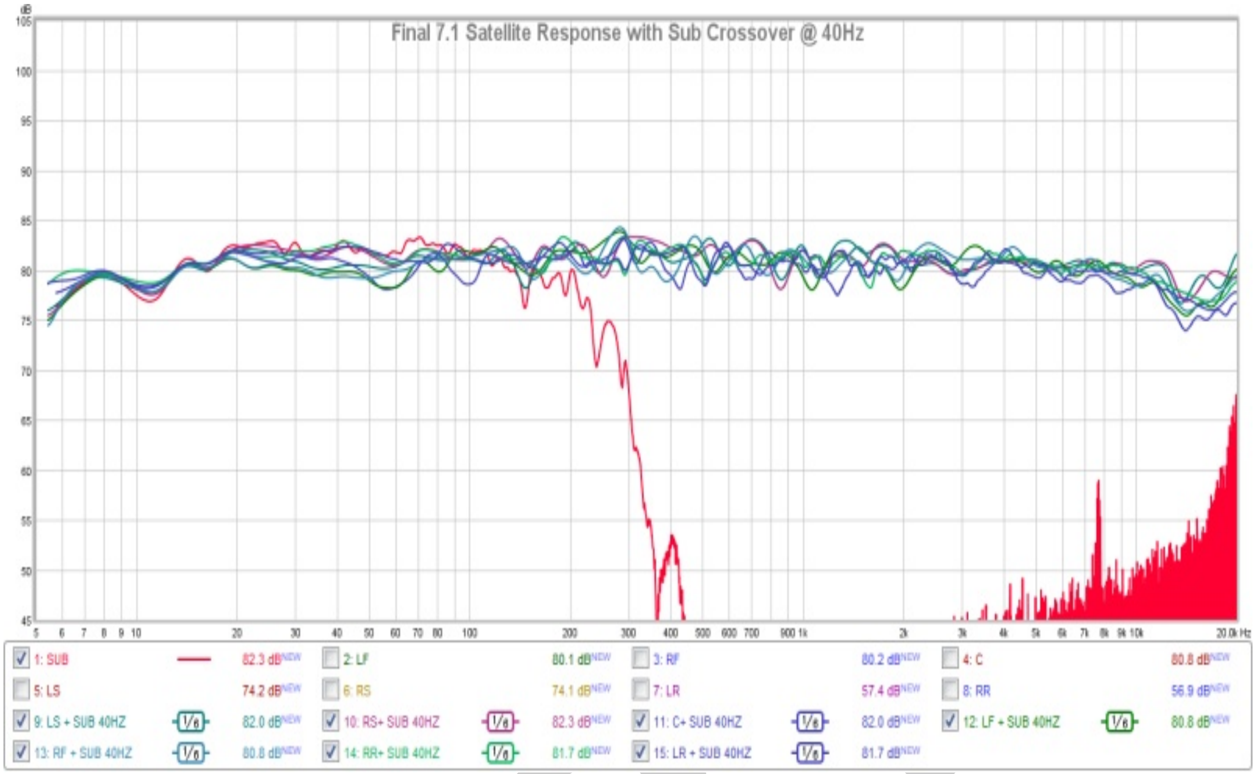
Notes:

1. The step response can also be used to investigate the transition from one speaker chassis to the next, and no obvious anomalies are seen there. It can be seen that the resulting step responses seem to indicate non-time aligned speaker units (typical). I am not too sure whether this is of any concern if, at the selected crossover frequencies, the units plus filters are in phase and create a flat frequency response. I trust that Genelec got this correct considering what they cost!
2. Ultimately, I am of course trying to phase align the subs to all the satellites bass units at/over the selected crossover frequency range. I am not an acoustical mathematician, but I understand that many knowledgably audio engineers will say that the use of the impulse response is not the best/correct way to do this. However, I understand that if the bandwidths of the measured devices are very similar, then aligning the impulse responses will work if the group delays (and phase response) are also very similar for both speakers. – They are, and it worked perfectly.

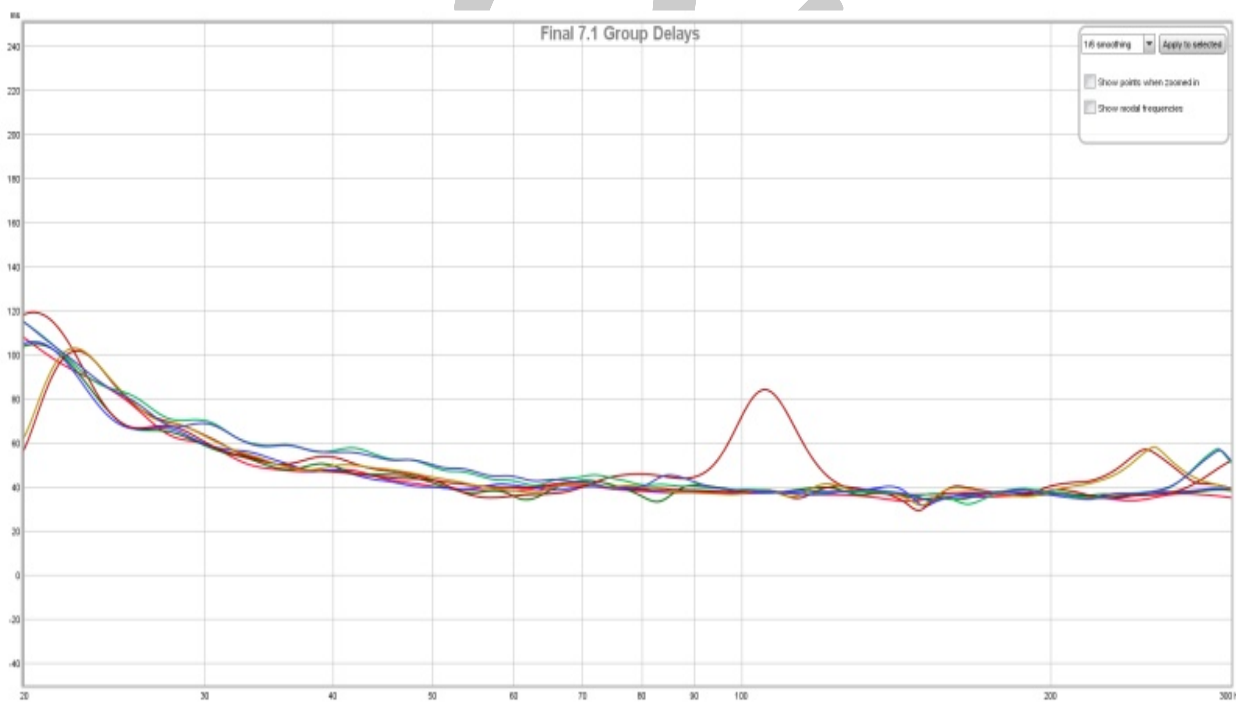
Final System Responses

The AVP sub delay *was not used to optimize the speaker's frequency responses* at the selected crossover frequency (40Hz) by adjusting it and monitoring the crossover region –'the sub tweak'. Final alignment ONLY relied upon the impulse response timing being time aligned together with matching group delays and phase responses, as shown above.

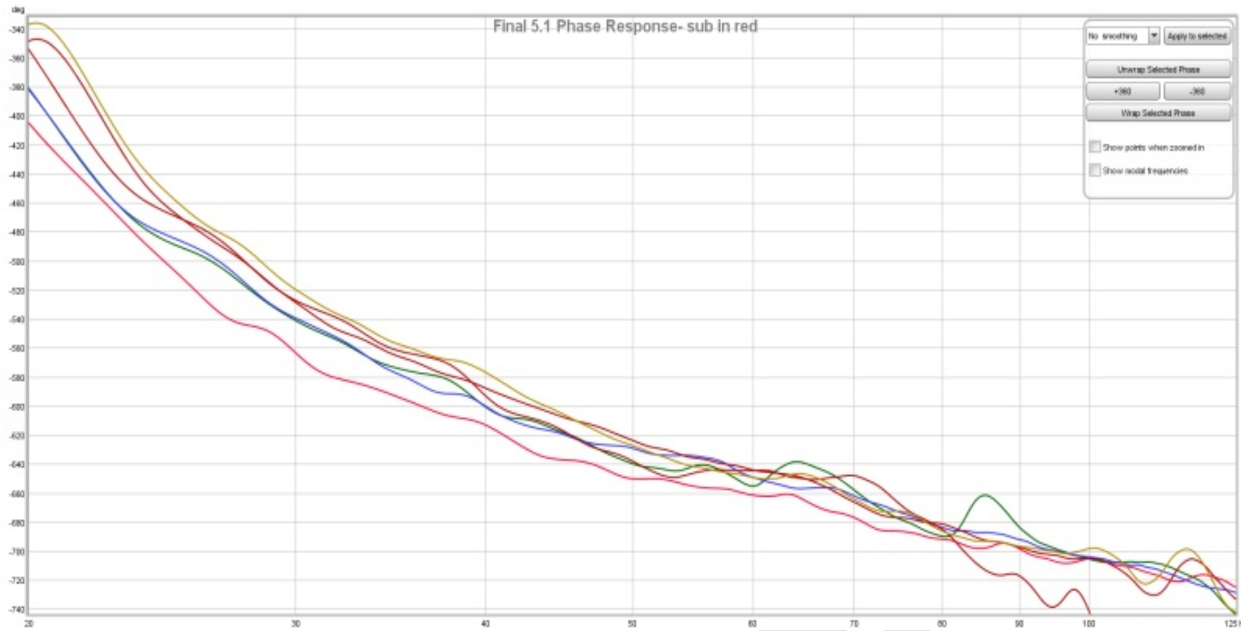
The following responses were taken with no adjustment to any parameters except switching in/out the 40Hz crossovers. Higher crossover frequencies produced a small dip at the crossover frequency requiring minor changes to the sub distance and causing it to be moved away from its IR time-aligned position in order to remove it; something I was not willing to do. Therefore, as the 1038's can support 30Hz at full power, 40Hz was settled upon as the final crossover. Care must be taken when changing crossover frequencies as these filters are produced in DSP's and the filter delay changed for each frequency selected.



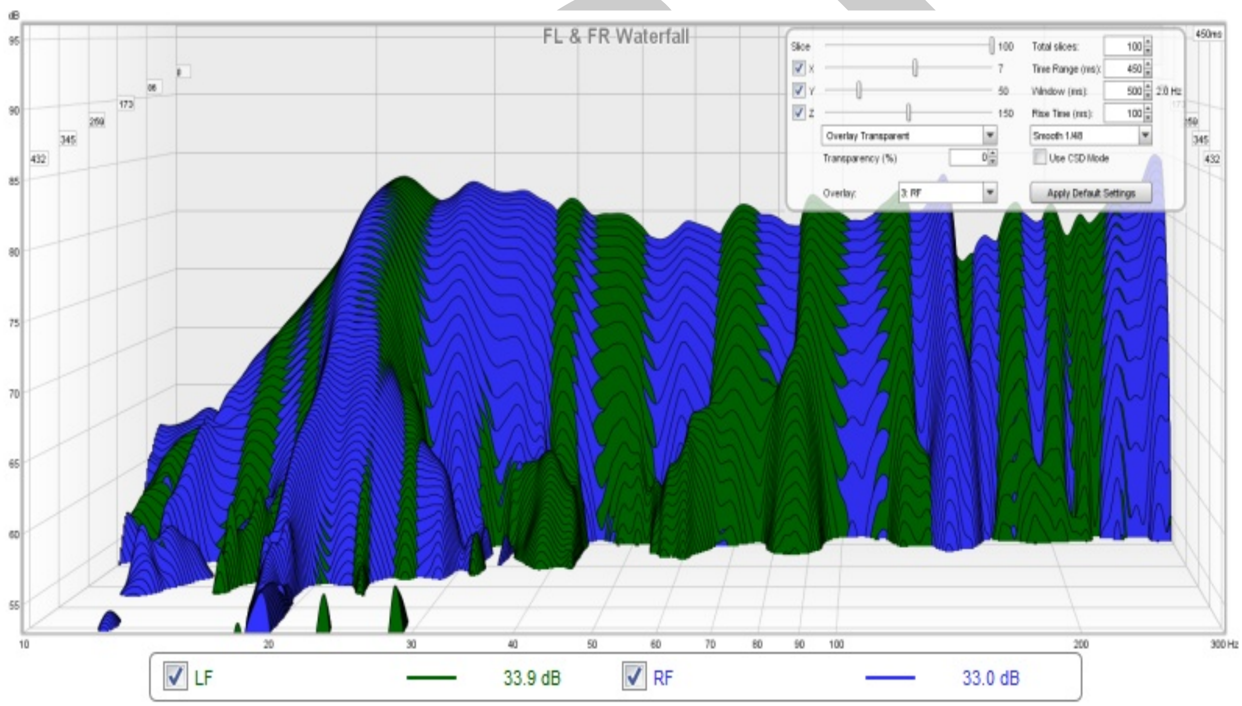
19. Frequency Responses with 40Hz Crossover – (The uptick above 15Khz is due to a sampling error.)



19A. LF Group Delays. All speakers and subs track well. The red and yellow curves are for the rear surround speakers. I make a comment later, regarding the delay anomaly on the center speaker at 105Hz.



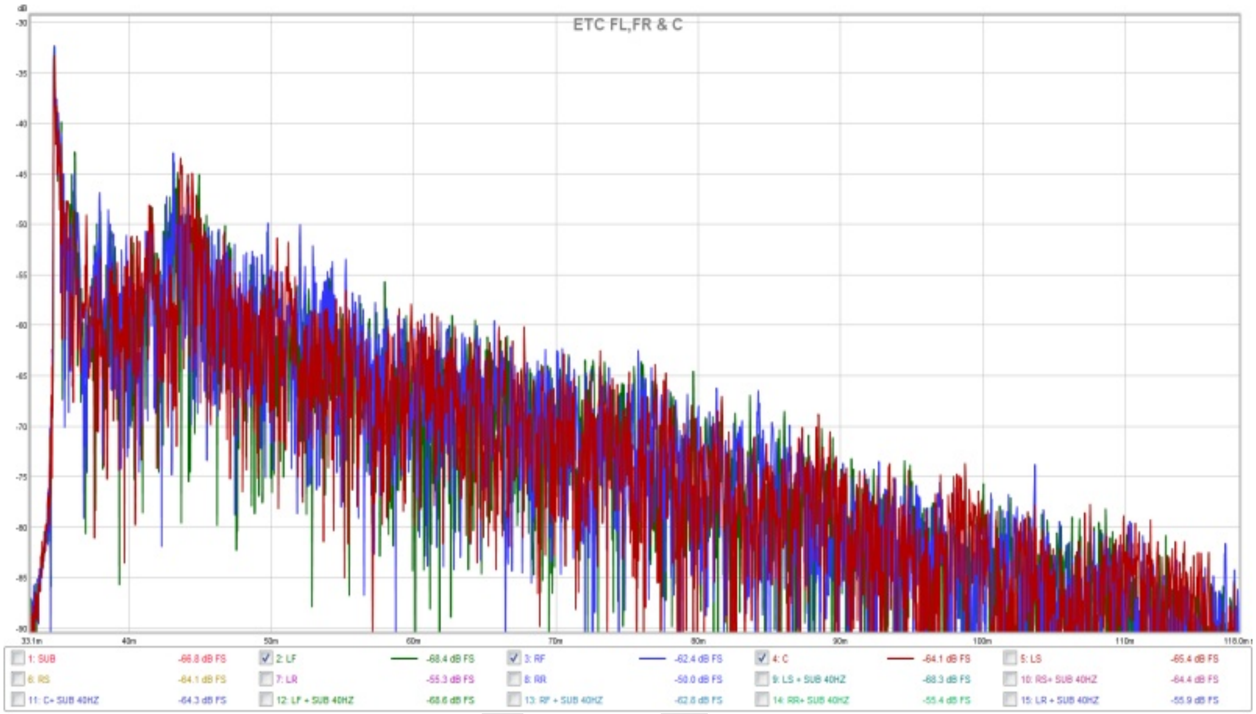
19B. LF Phase Responses - The sub and satellite group delays/phase responses track well.



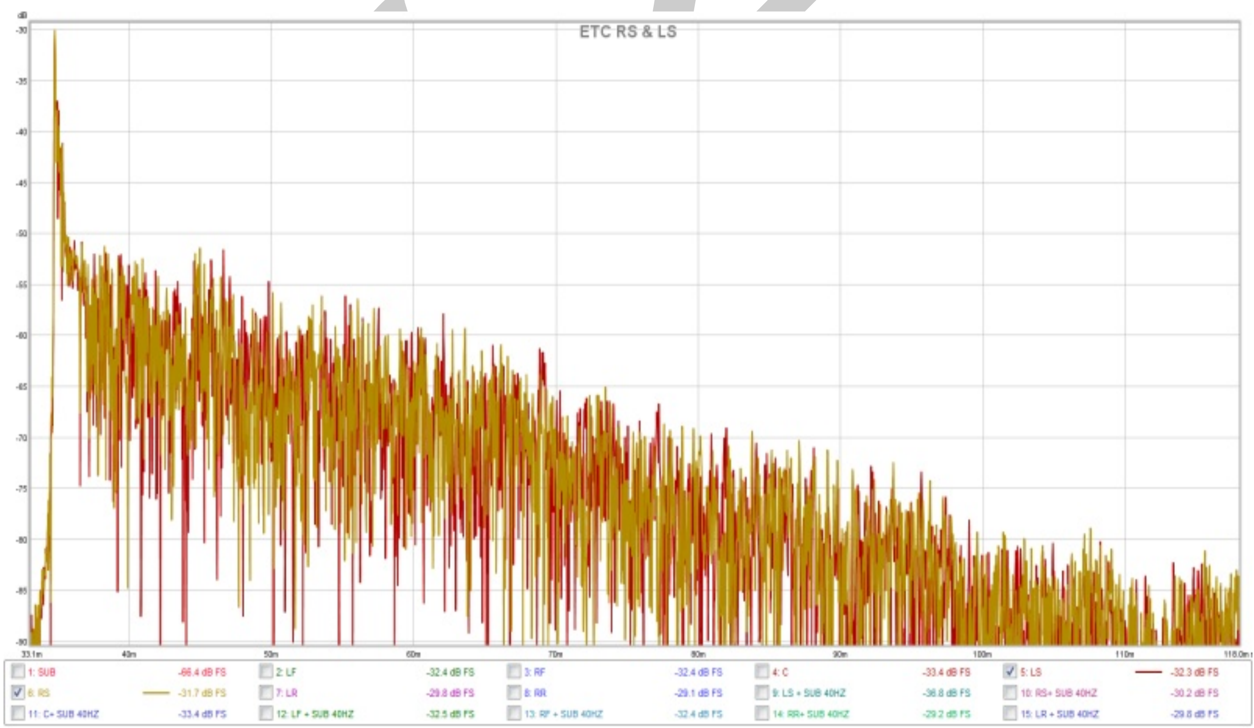
19C. Satellite Waterfalls – FL/FR

I included these waterfalls just for comparison; as for most of my stereo music listening I do not use my subs. There is a small-extended decay at 20Hz, but it is not of any concern to me, and cannot be detected by me as coloration.

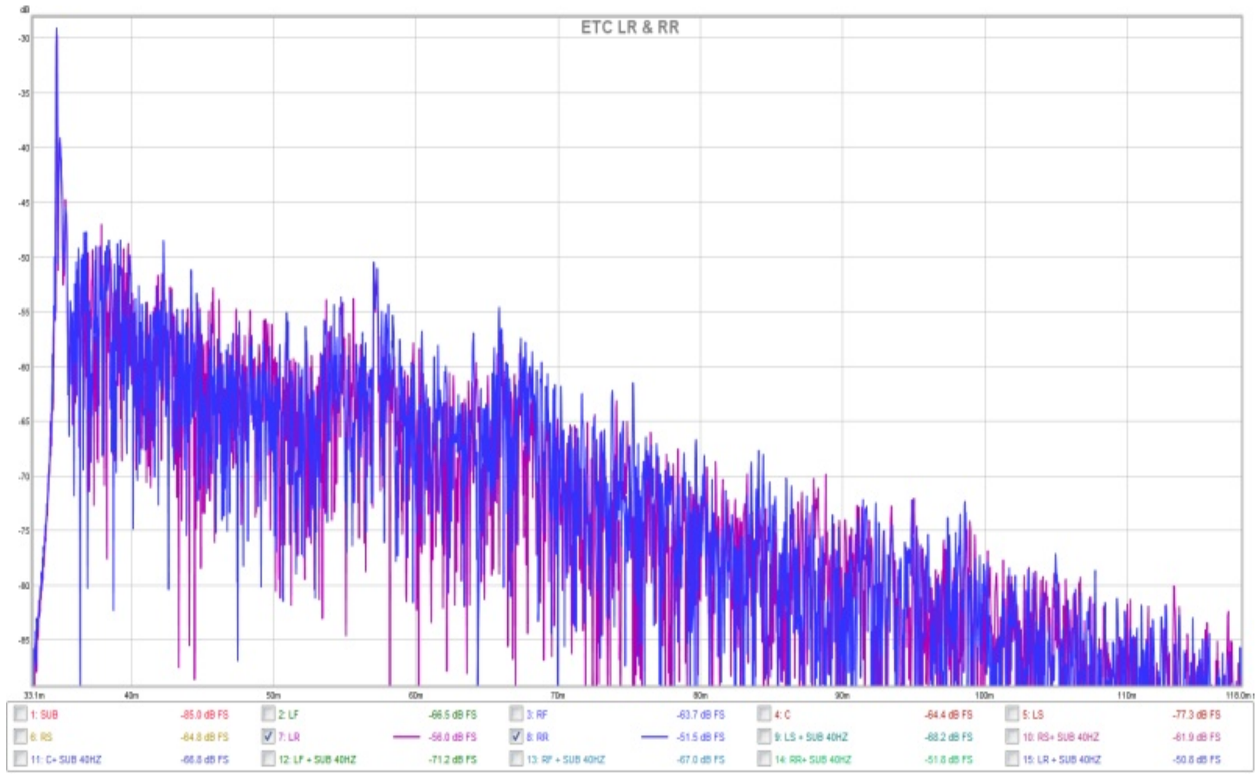
Note: No attempt was made to try to eliminate any of the very early reflections around 36mS that come from the leather chairs in any of the following LF/C/RF ETC responses:



19D. ETC Responses – 1038 LF/RF/C



19E. ETC Responses – 1038 LS/LR



19F. ETC Response – 8040 LR/RR - The reflections at 57mS and 66mS for the rears are caused by the center speaker box and room front carpentry, and cannot be eliminated, but are at a level and time so as not to be problematic.

All reflections are similar in nature achieving approximately -20dB in 1.5mS for the front speakers and -20dB in 0.6mS for the surrounds and rears respectively, and can be considered as satisfactory.

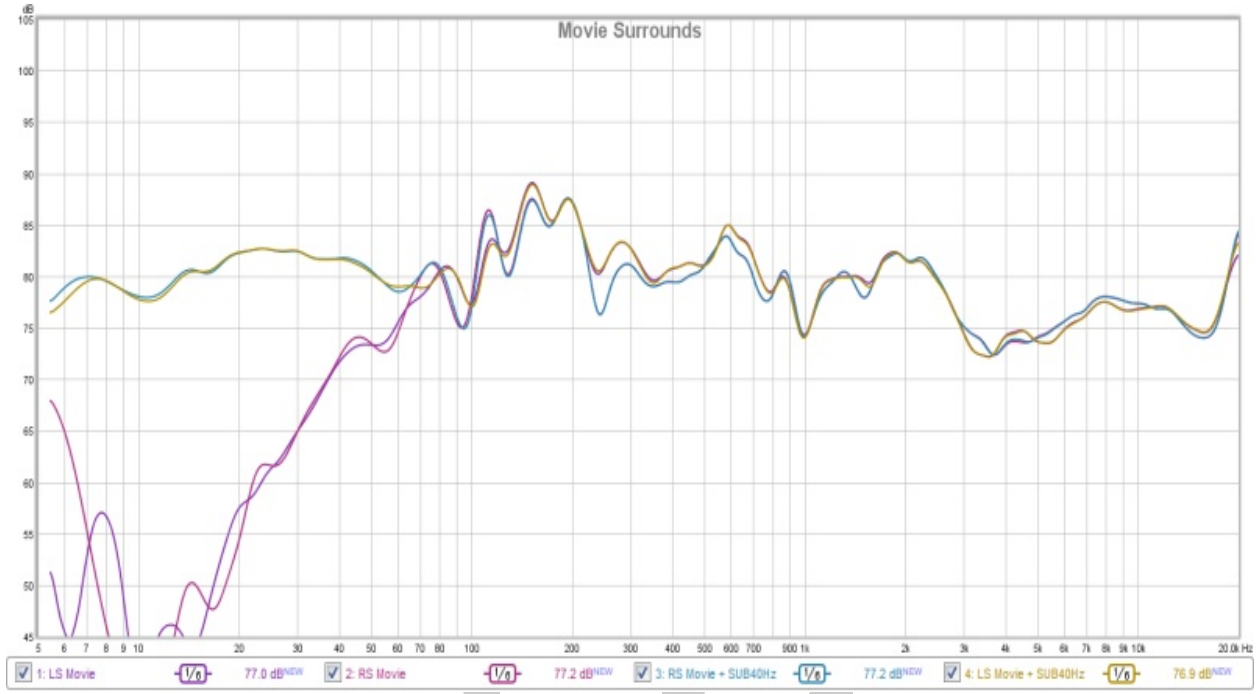
The raised level of reflections (Kicker Delay) shown in Graph 19D at 43mS (9mS after initial impulse) is deliberate and to be expected, and does not appear to interfere with imaging. It comes from the diffusion created by the rear quadratic residue diffuser (QRD). This QRD has a cut off frequency of approximately 1KHz. With the MLP being 4' 10" in front of the QRD, it is at an acceptable distance from it, to reduce lobbing problems from the +1, +1, -1, +1 QRD configuration. To see if the QRD was causing imaging problems I placed 8" of absorber across its entire surface, causing the 9mS reflection to be completely removed. To my ears it had no effect on imaging, but it did make the room sound a little flat with a 'hole' behind me. I did not try to re-EQ the room with this absorber in place…enough was enough by now.

Small 8040 Movie Surrounds

The system is equalized for the large 1038 surrounds for multi-channel music. For movies the smaller sidewall mounted 8040 surrounds are utilized with a crossover of 40Hz. This has the unfortunate effect of using the 1038 AVP XT32 EQ for the 8040's…not the best of choices, but a lot better than the other way around.

Now you know why I choose to set both pairs of surrounds at the same distance from the MLP and to have the same sensitivity. They were both to use the same Audyssey EQ settings.

The following graph shows the effect of using the 1038 EQ on the 8040 surround speakers.

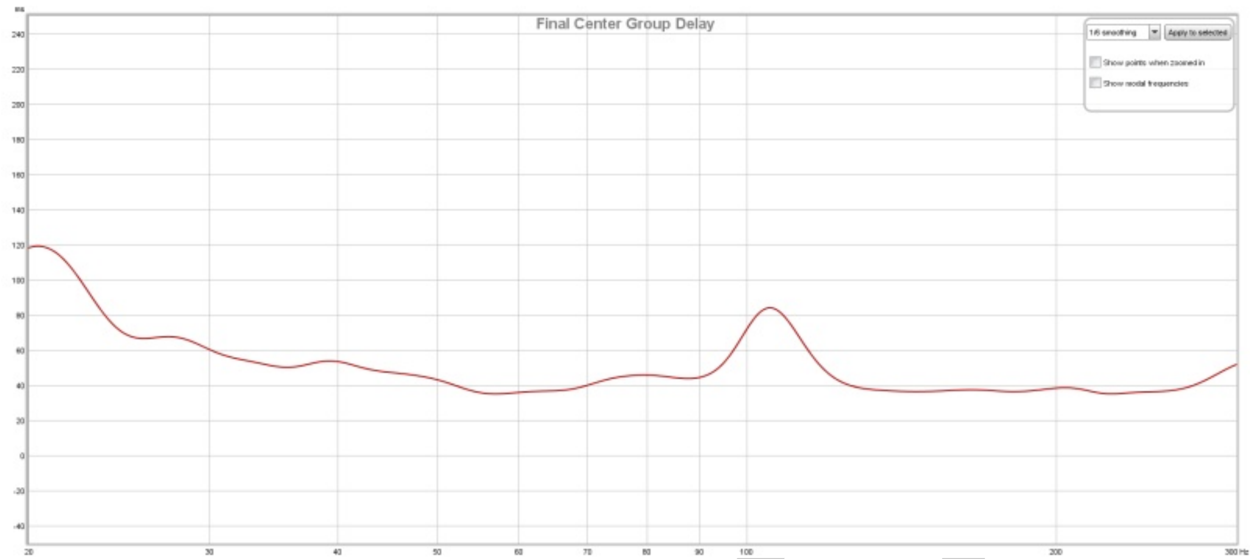


20. Side Surrounds (8040's) Frequency Response using the 1038 EQ

As these are movie only surrounds I have listened to what you see above and then loaded a second EQ that used the 8040's as the primary equalized speakers for surrounds. To be honest, I couldn't really hear much difference…they are, after all, just surrounds, well diffused and well above ear height. They were just slightly more prominent in the surround mix when correctly equalized. The issue could be rectified by adding another level of EQ to support just these two surround feeds, or by uploading the saved EQ for the 8040's (a slow process), but I am not going to do either as the audible difference was not great enough to impact my enjoyment of a movie.

Center Channel Group Delay Anomaly

There is the only anomaly that is bothersome to me, even though I seem to be unable to hear it. The group delay issue at 105Hz on the center speaker, see below.



21. Center Channel Group Delay

It is related to a phase change with the signal at that frequency. I originally thought it was as a result of the path length to the QRD on the rear wall. However, I can only remove it by:

1. Moving the mic at least 12” forwards – this doesn’t move the GD peak to a different frequency, it simply goes away.
2. Putting up absorber panels on each side of the center speaker – see photo below.

22. Center Channel with absorber panels

Point 2 would seem to indicate that it has something to do with side radiated sound, as the center 1038 LF units that handle 105Hz can be seen to be composed of two smaller units, one each side of the speaker.

Covering the whole of the rear QRD in 8" of Roxsul doesn't change the problem, indicating that it is probably not caused by a rear reflection. I'm tired and stumped!

If any reader has any ideas or a pointer as to what is causing it I would be very grateful. All the room drawings and dimensions in these posts are accurate.

Final Listening

- Bass – tight, clean and extended with plenty of level and punch; very well integrated into the overall sound, no obvious coloration or resonances. For some music mixes the bass sometimes seems to be at too low a level to what I remember, but I assume that is because it is now less colored. Using dynamic EQ or raising the sub level, if in use, will immediately rectify this.
- Mid-range – still a little too forward/hard but plenty of presence and clarity. How forward/hard varies quite markedly between mixes. As the response is quite flat I *assume* it is a mix/speaker issue. Interestingly, it is never too forward/hard for movies.
- HF – clean and detailed
- Imaging and sound stage – sharp and deep

Final Comments

Music - Stereo & Multichannel (and movies).

The AVP has a nice feature called *Direct* that allows the user to run all speakers, either with or without crossovers to the subs, just at the touch of a button. It's interesting to note that there is clearly no standard for either levels or crossover frequencies for the 0.1 channel when utilized for music. This resulted in the use of subs not always being beneficial to the overall LF music reproduction. On top of that the 0.1 channel is full bandwidth when used in music only mixes (and now apparently also for some film mixes), it can therefore contain 'spill' from other instruments. I have found that often there isn't much information in music below 30Hz unless it's an organ or electronic, even kick drums in some 5.1 music mixes have virtually no content in the 0.1 channel. I can monitor this as the Rane has LEDs' that light if there is any significant LF content being sent to the subs.

Despite the *relatively* poor decay of the 1038's at 20Hz and lack of response below 20Hz when compared to the subs, extending their response using the subs with a crossover of 40Hz, has either:

1. Little audible effect – for most of the time, even if the Rane LEDs' are lit
2. Can make the LF slightly heavy/thick

The benefits of the subs for most stereo music is *very* dependent upon the mix, so generally I rarely use them, unless I know they are required, or it is 5.1, and then I generally only use direct mode (no crossovers). However, I always use the 40Hz crossover for movies as I have found that there is often a significant amount of LF energy placed in the front channels. The 1038's are not meant to handle high levels below 30Hz so crossing over to the subs significantly reduces distortion at the low frequency, high SPL's often encountered in movies. All other smaller satellite speakers use the Audyssey recommended crossovers for movies or music.

Well, that is it for now, happy? Yes. I may change my front PB12's for SB2000's but I am not too sure what that will gain me, other than maybe an easier setup procedure and maybe help with the 16Hz and 27Hz decays.

I really need a new projector and player, so saving for the 4K revolution now.

In closing I just wish to say that the following movies produce some astonishing LFE sub action:

- Edge of Tomorrow – opening scenes - awesome!
- Mad Max – Fury Road
- Furious 7
- Tron
- Oblivion
- Interstellar

I will continue to update the associated posts as I make changes to the room, but it might be a while.