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Bass Management
PART 5

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SPELLBINDING HOME ENTERTAINMENT

Widescreen Review Bass Management **PART 5**

I'll say it one last time in this final part of the quest for bass kickage!
"Really good bass is hard to get!!!"

In the first four parts of this series on bass management, we covered the important steps in getting to loud, tight, punchy bass throughout the listening area. I think of the whole process as a 7-step strategy. As a reminder, here are the highlights:

1. **Room Dimensional Ratios**
2. **Bass Damping**
3. **Seating Locations**
4. **Subwoofer and Speaker Locations**
5. **Subwoofer and Speaker Selection**
6. **Subwoofer Crossover Settings**
7. **Tuning (Time Optimization, EQ, Levels)**

I bet you never thought it took this much effort to get good clean bass. Neither did I when I started down this rabbit hole about 25 years ago! With a lot of experimenting, reading of scientific journals and a pile of books, and talking to several experts in the field of acoustics and speakers, I am starting to get a picture of the solutions - just starting! In this part we are going to talk about that last step, Number 7, which is to tune the speaker and subwoofer system in order to get smoothest, loudest, and most dynamic response.

In Parts 1 through 4 of the article series, I went through steps 1-6, and we can now get down to optimizing how the bass drivers interface with the room and to tuning the frequency and time response for smoothest results. Remember that bass does not only come out of the subwoofers. Some of the bass region is handled in the speakers, and the tuning process will involve all the speakers and subs in the room.

This 7th step will largely involve optimization of the bass response through electro- acoustical measurements of the speakers and subwoofers, and trial and error placement plus electronic signal processing optimization of the speakers and subwoofers. You will definitely need to rely on sophisticated acoustical analysis tools, but the good news is that they are quite cheap these days.

GATHER THE RIGHT TOOLS

You will need a MEASUREMENT MICROPHONE, which can be one of the simple but effective USB test mics such as the Dayton Audio UMM6 or the UMIK-1. You can also look at the Behringer ECM8000 if you have a microphone preamp and USB interface. For the best work, you can get four omnidirectional audio test microphones and a switcher, called a multiplexer. That gets a bit more expensive, but remember that you are tuning high-end systems that cost a lot and took a lot of time to install and integrate; it's a reasonable balance!

Get a BOOM MIC STAND - one that you can easily swing around the base location in order to get an average of the response around the arc of the boom extension. If you use four mics and a multiplexer, you will need four mic stands. Manfrotto makes some nice compact stands that will do the trick (https://www.manfrotto.com/us-en/black-aluminum-mini-pro-stand-156blb/).

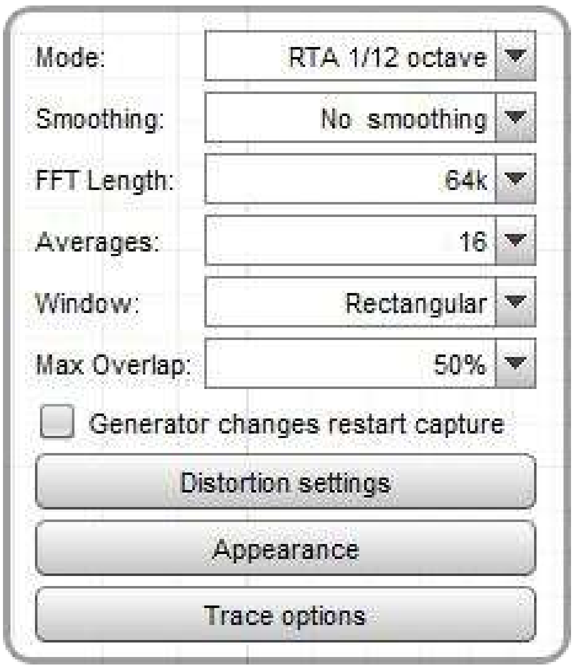
Whether it's a single boom or four individual mic stands, you will place them in various locations around the listening area so as to get spatially-averaged measurements and observations that match what you hear in the room.

You will also need an acoustical measurement and analysis application. I suggest getting Room EQ Wizard (REW), which is a free download (please give them a donation for all the excellent work they have done over the years). For some measurements, you will need test discs. The 5.1 Audio Toolkit DVD (yes, it's old) or any of the Dolby Atmos Blu-ray demo discs. Both of these are available for purchase online.

It is also important to be able to feed test signals from the REW application right to your sound system. You can do this through an HDMI output from your laptop, through an analog output of either your laptop or your USB interface, or even an SPDIF feed from your interface if you have one of the higher end ones such as the USBPre2. Sometimes the surround decoder is far away from the room to be tuned, so you will need to plan on running a long extension. Avoid feeding unbalanced analog audio any longer than 20' in order to avoid noise, hum, and response errors along the way. Balanced audio can make it much further. With HDMI, you can use an electronic Balun feeding a long Cat5E or Cat6 cable. I have also used some of the better-quality wireless mic signal converters that you can get from pro audio suppliers such as Sennheiser or Shure. Yes, it's a single channel, but in most cases, you are feeding only one channel into the system at a time, measuring it, and optimizing it.

OPTIMIZING SUBWOOFER PLACEMENT

Ideally, you have done some modeling and decision-making much earlier in this 7-step process, but if you are lucky to still have some flexibility in the placement of your subwoofers, go ahead and spend some time observing the effects that small location changes have on the resulting bass response and levels. You will be amazed at the changes resulting from moving subwoofers just a few inches. That's because the interactions can be complex and dramatic. So go ahead and take some time to play with this, and if you have multiple subwoofers, run them all at the same time. I do recommend placing the subwoofers on small dollies so that you can save your back muscles and so that you can observe the results of the movement just as it is happening. If you are using REW, select the Pink Periodic mode for the signal generator, and use the RTA measurement mode, with the settings as shown in this screen print:



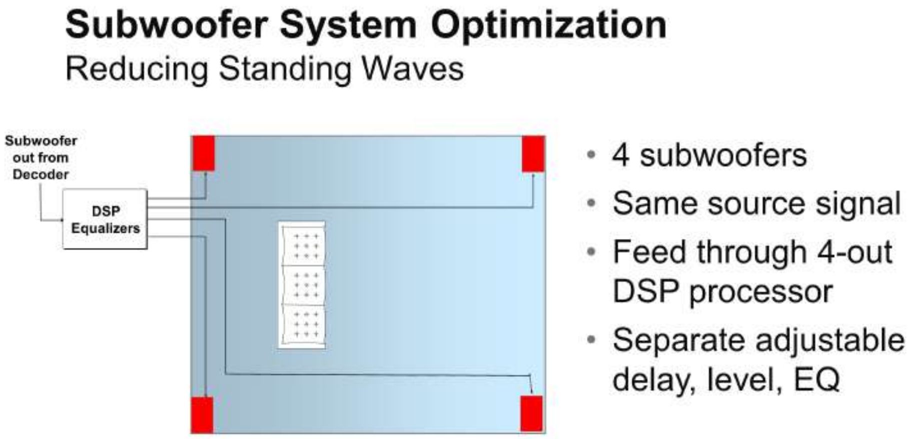
OPTIMIZING SPEAKER PLACEMENT

As with the subwoofers, you should already have done some modeling and decision-making on speaker placement much earlier in this 7-step process. If you are lucky enough to still have some placement flexibility, go ahead and try moving at least the three front speakers around to see if you get any improvements in bass smoothness. Here again the effects can be dramatic! Boundary reflections, especially multiple coincident ones, can create irrecoverable mid-bass cancellations - all of which can be alleviated with some small placement changes (see Part 3 of the series for more on this). Of course, in home theaters you are also trying to maintain a correspondence between the sound stage and the image location, so this can get tricky.

SET INTER-SUBWOOFER DELAYS

If, as recommended, your system has at least two or better yet four subwoofers, this can be the most fun part of this long drawn-out process, because you can observe and hear radical effects of simple signal processing corrections. Let's discuss the steps you would go through if you had placed four subwoofers in the four corners of the room, as I presented in Part 3 of this series. Note that this is my preferred start point, as it has repeatedly shown to be the best compromise between bass smoothness and overall signal gain. The sequence of steps below can allegedly be automated through one of the optimization systems that claim to get the best results. So far, I haven't been able to find one that beats the manual process - either in resulting response, or in amount of time needed for the process. Let's hope that the all-new touted AI technologies can improve upon this!

a. Feed the same signal to the subwoofers. Use one output from the surround processor containing the entire bassredirected signals plus LFE channel. Connect it to the input of a digital signal processor that provides four outputs with independent control of delay, level, and EQ, as well as overall frequency response equalization. This processor could be an external box, such as a Dayton Audio 4x8, MiniDSP 2x4, or other digital EQ device. The signal processing can also be built right into your surround decoder, such as in Storm Audio or Trinnov devices. See Figure 2 below.



b. Measure the bass response from 15 Hz to 300 Hz using RTA with 1/12th octave resolution and temporal and spatial averaging, as discussed above. Expect a rough-looking response due to standing wave resonances, boundary conditions, inter-subwoofer interactions, and more.

c. Start a trial-and-error sequence of delays for groups of subwoofers. Add 2 ms of delay to the two back subwoofers, and observe and record the result. Try 4 ms of delay for the two back subwoofers, and observe and record. Go up to 6 ms, 8 ms, 10 ms, and even 12 ms of delay in the two back subwoofers, and observe and record the data results. Then zero out all the delays, and do the same trial-and-error of delays for the two front subwoofers, starting at 2 ms, then 4 ms, 6 ms, 8 ms, 10 ms, and 12 ms. Then zero out the delays, and try delays on the two left subwoofers, then the two right subwoofers. At this point in time, you will definitely detect trends. Sometimes, the delays do nothing to improve or change the overall frequency response. But often you will see significant shifts in the response. Aim for improved response in the lower frequencies. A 3 dB rise in level in the ½ octave around 25 Hz is worth it, as you will then be able to reduce the driver displacement where it may be the most challenged.

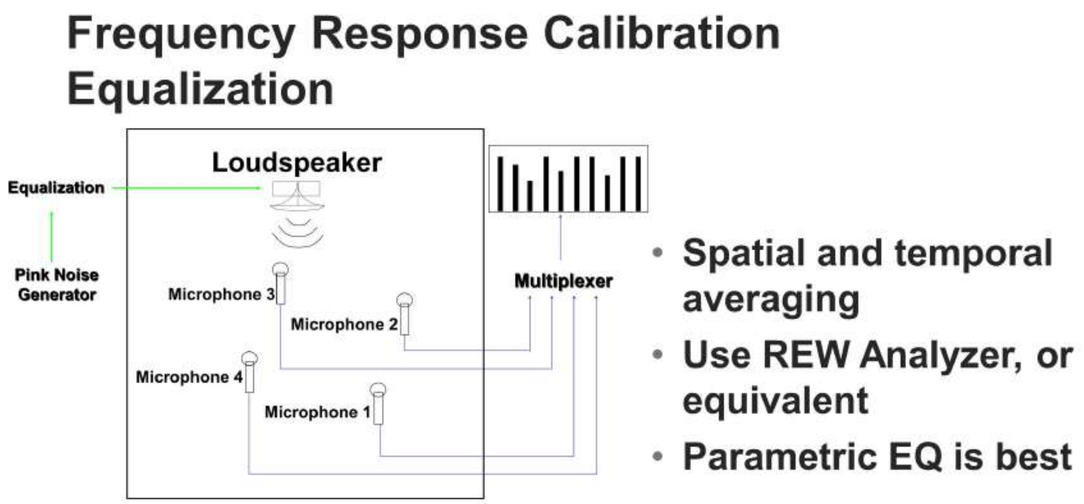
d. In addition to observing the overall room response with spatial averaging, also check the differences in response at the various seat positions. Remember that the goals are: (1) smoothest overall response, (2) highest gain – especially at lower frequencies - and (3) lowest seat-to-seat variation. It will take some time to get through the various steps of delay time optimization, but it is well worth the exercise. I usually reserve at least an hour of time for this process; it sometimes produces a very significant increase in bass output.

SET INTER-SUBWOOFER LEVELS

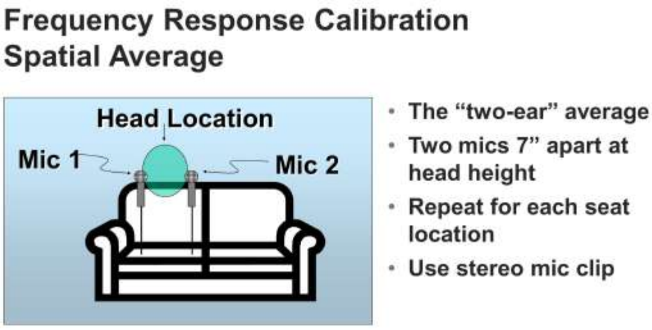
This optimization sequence is very similar to the Inter-Subwoofer Delay investigation, but consists of observing the effect of adjusting individual or group levels in the subwoofer system. Follow the same steps as above, but go in 2 dB increments of level, starting with the back subwoofers, then the front, then left, and then right. If you're using REW, you can store each of the resulting data curves and look at them in overlay mode. You can tell a lot from this process of trial-and-error and observations.

ADJUST FREQUENCY RESPONSE

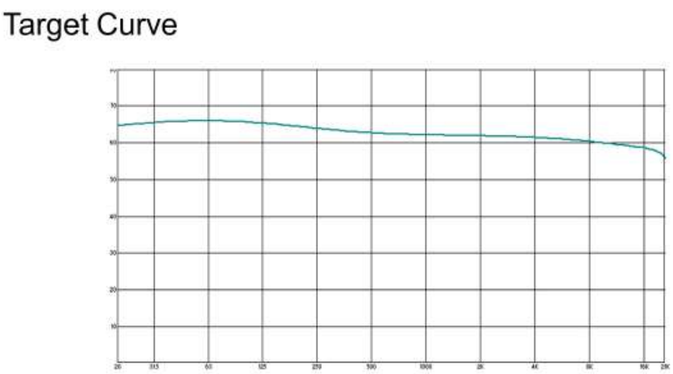
Once you have found the combination of Inter-Subwoofer Delays and Levels that yields the best balance of response smoothness, gain, LF extension, and seat-to-seat consistency, it is time to smooth out the overall frequency response with parametric equalization. To make this all work with relevant results, you do need to get a set of measurements from at least four points in the listening area, and you do need to understand how to do proper parametric equalization correction. I started writing about this process, and two pages into it, I realized that it would take about five or more pages - and that this article series is not a course on acoustical analysis, room correction, and equalization. There are several good tutorials online, so go take a look there. The figure below lists the important points of the setup.



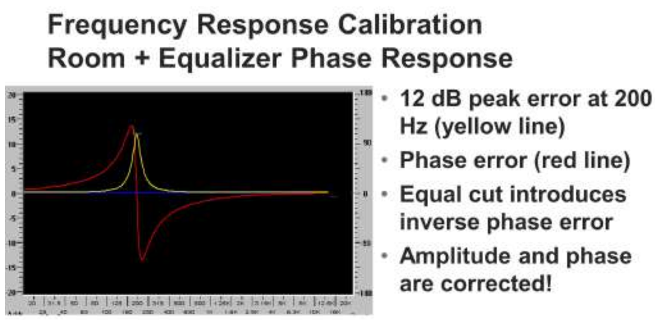
If you are working in a room where the main listening position (MLP) is the most important, you can bias the measurements toward that target area by placing two of the microphones there on a stereo microphone clip, as shown in this figure:



The bottom line is that through a successive process of measurements and parametric equalization corrections, you should arrive at a smooth response from 20 Hz up to 300 Hz (if your subwoofer sizes allow) or at least from 30 Hz to 300 Hz. Extensive investigation into listener preferences have shown the that the bass region up to about 120 Hz should be louder than the median mid-frequency level by about 5 dB, and it should follow what is known as a home cinema target curve, as shown in the figure below.

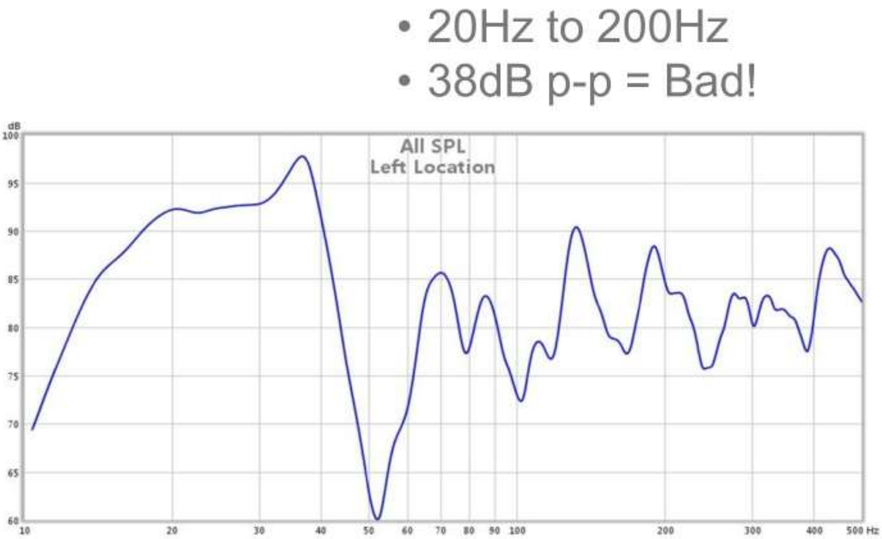


At this point, a few of you may be bristling at the idea of applying parametric equalization, since you may have heard that it distorts the signal or - worse yet - that it messes up the phase response of the sound. Both of these notions are erroneous and are bad legends. Properly done measurements and EQ will linearize both the Amplitude vs. Frequency and the Phase vs. Frequency responses. Realize that a peak in response introduced by typical room acoustical issues that are known as "minimum phase" will necessarily result in a rotation in phase response that is predictable mathematically. A correction dip of the inverse amount will also introduce an inverse phase rotation, which will result in linear phase overall. Be careful of hearsay in all aspects of life, including audio engineering, where there seem to be a lot of false legends!

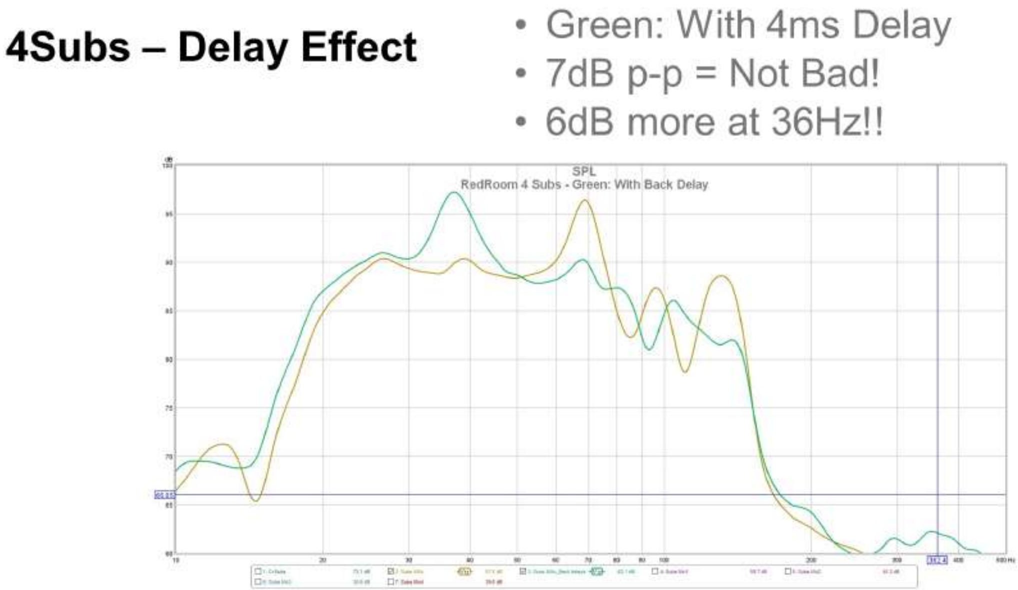


Now for the fun part. Here is a sequence of actual in-room measurements showing the original response with four subwoofers driven identically, then with delay and level optimization, and then with equalization to smooth out the results.

Room 1: The room that started this whole series! Remember this horrible response at the MLP, from a subwoofer placed in the front left of the room? Errors were up to 38 dB!

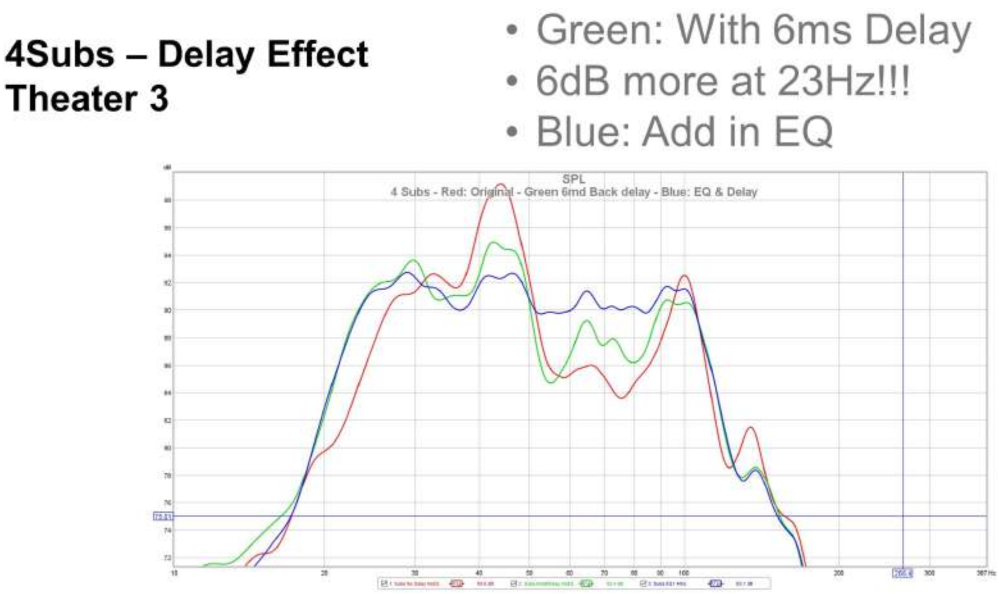


Here is the result of switching to four subwoofers (brown curve), then conducting inter-delay and inter-level optimization between the four subs (green curve). Almost smooth! There was a 6 dB level boost at 36 Hz, which can be equalized down to spare the driver excursion for increased bass headroom! The next step is to equalize the subwoofers to match the rest of the speaker system and to optimize the bass crossover region, as we discussed in Part 4. Everyone that heard this room was amazed by the improvement.

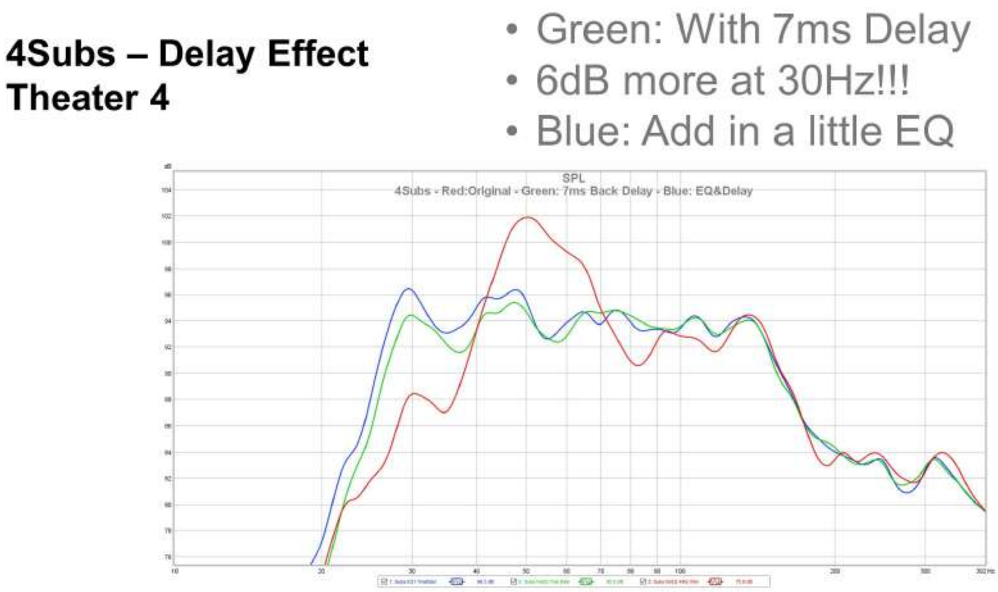


Room 2: Here is the response from four subwoofers before (blue curve) and after inter-delay and level optimization (green curve). Got 4 dB more level at 22 Hz from the process - very worth the effort! Next step is to reduce the 70 Hz peak with parametric EQ, and the result is tight and loud bass.

Room 3: Here is another example of the response from four subwoofers before (red curve) and after inter-delay and level optimization (green curve). This optimization yielded 6 dB more output at 23 Hz for room shaking bass without excessive amplifier power. Add equalization to tame the peaks and dips, and the curve looks nice and smooth (blue curve).



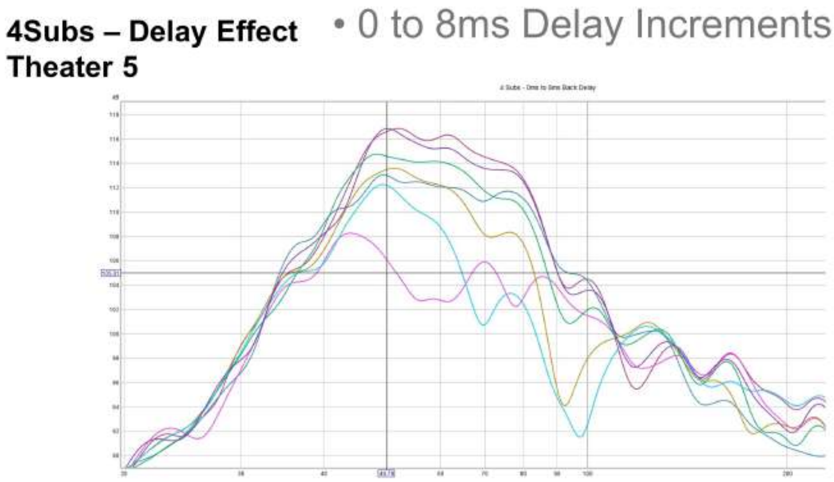
Room 4: Here is yet another example of the response from four subwoofers before (red curve) and after inter-delay and level optimization (green curve). This optimization yielded 6 dB more output at 30 Hz. Add a bit of equalization and you get a smooth curve (blue curve).



Room 5: Here the most astounding example I have come across yet of the benefits of bass processing optimization. In this room, the process yielded a full 12 dB gain from 40 to 80 Hz.

You would have to throw enormous amplifiers at these subwoofers to achieve the same result. The red curve shows the response before optimization, and the green curve shows the response after inter-delay and inter-level optimization. The next step would be to tame the broad peak centered on 58 Hz and to enjoy the loud and punchy bass effects.

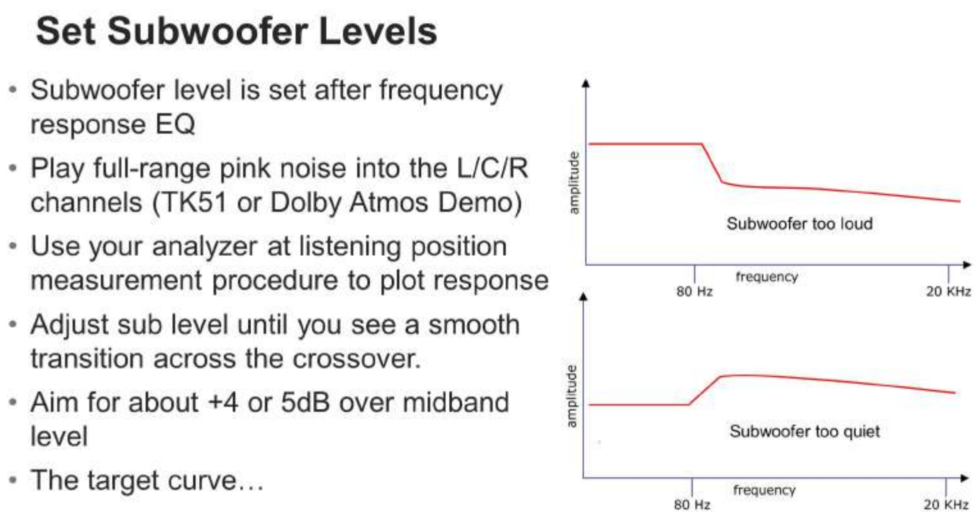
Just for fun, here is the measured and recorded progression from 0 ms to 8 ms of delay on the back subwoofers in this room. Note how clearly visible the improvements are. In your work, you should absolutely record every permutation of delay and level so that you can look through the volumes of data and make the right decision on the bass optimization settings.



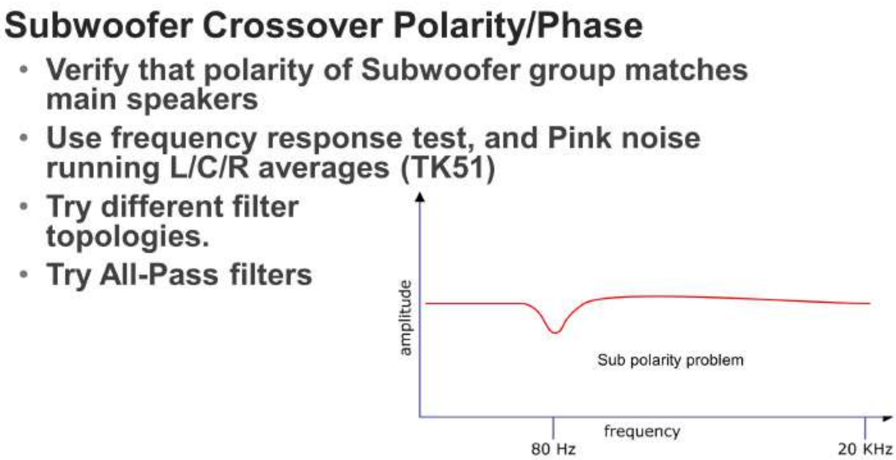
FINAL STEPS

Once you have found the combination of Inter-Subwoofer Delays and Levels that yields the best set of compromises, and you have equalized the subwoofers for smoothest response, it is time to set the overall subwoofer system gain and mess around with the crossover fine tuning a bit.

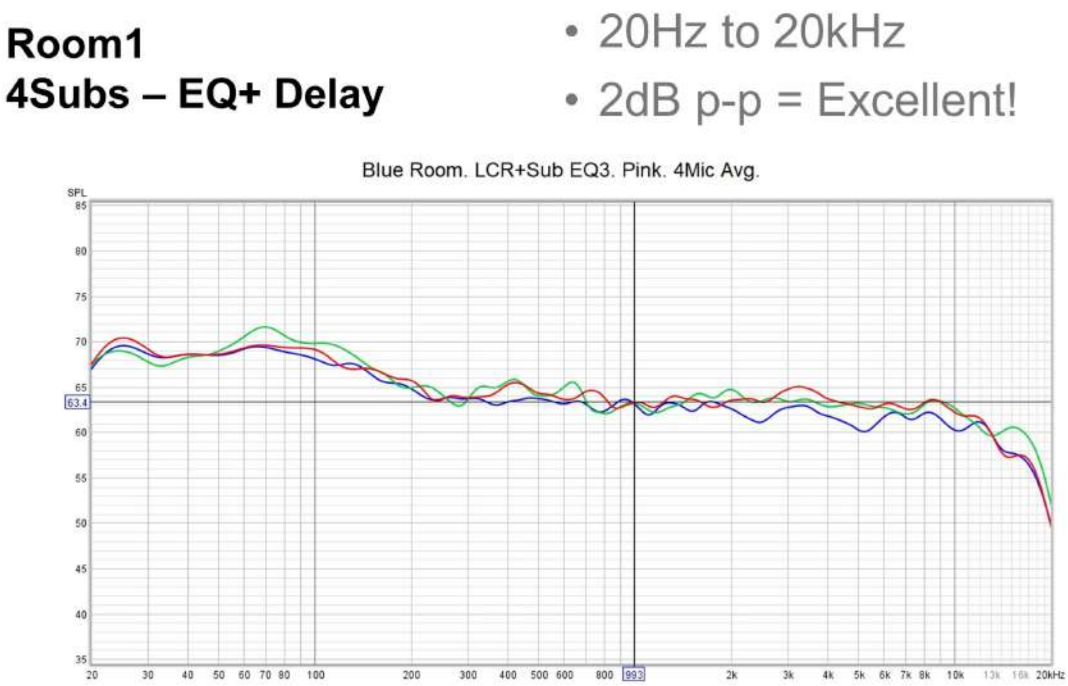
Use either Wideband Pink Periodic from REW in the Left, Center, or Right feeds, or use the Left/Center/Right circulating Wideband Pink Noise on the 5.1 Audio Toolkit (Title 1, Chapter 15), or use the L/C/R Wideband Pink Noise on the Dolby Atmos Blu-ray demo discs. Measure the overall response of the system and work on getting the level to match the target curve shown above.



You may notice that the region right around the subwoofer crossover may show a slight dip, and that even a bit of EQ can't quite get it back. This may result from a relative polarity issue between the subwoofer system and the front speakers, or it could be the result of phase errors between the two. Rather than push a lot of signal power over that region, try switching the polarity of the subwoofer system or try changing the filter slope or topology (Butterworth / Linkwitz-Riley / Bessel) or try applying an all-pass filter to the subwoofer system or to the speaker channel that does not match up.



At then end of this whole process, you should have worked up to a point where the frequency responses of the three front speakers are all smooth, all similar to each other, and all follow the industry-standard target curve. The curve below shows Room 1, after all the work we discussed, for the Left, Center, and Right speakers.



This curve set above shows smooth responses, and follows the target curve. You can see a small divergence in the region from 2 kHz to 6 kHz. This curve set was measured after extensive listening tests, during which the perceived timbre of the three speakers was equalized by ear until they matched perfectly. This was not a solitary effort. Three listeners contributed their "subjective" impressions of the character of pink noise and music across the three channels. The measured and perceived responses didn't quite line up, due to complex acoustical issues, and what matters most is that the three front speakers sound identical. This leads me to the next and final topic: Listening Tests.

LISTENING TESTS

Some think this is the best part of the process. Instead of listening to Pseudo-Random Periodic Pink Noise, or signal sweeps, or whatever other synthetic test signal your analysis system throws at your speakers and subwoofers, you get to listen to actual music and movie soundtracks. That's great, but you need to know what to listen for. You should know the program material very precisely from having heard it hundreds of times (that's less fun), and you need to be prepared to make careful corrections based on little subtleties you notice. The fact is that microphones do NOT listen the same way that the ear-brain system of human beings does. Broad errors are absolutely measured to be the same as what you hear, but subtle elements are not always visible on computer plots, and temporal and spatial cues may not show up at all on even the best analysis gear. So, yes, go ahead and take break, come back with refreshed mind and ears, and spend at least an hour or two listening through your catalog of carefully-curated program material. I like to start with pink noise playing one channel at a time all the way around the room. I listen for consistency of spectrum and level, verifying that the bass character is equal all the way around. Then onto program material with both subtle and heavy bass content. I may play with the subwoofer system gain until all elements fall into place. Sometimes it's just a matter of 1 dB up or down from what the measured target curved indicated.

In the end, when there is thunderously punchy bass, you should feel the gut punch. When there are subtle bass elements of cellos and double basses in a Mahler symphony, they should sound like you are at the concert hall. I contend that if you do all of the above correctly, the same system with the same calibration will faithfully reproduce the bass content of both music and movies without needing any form of tuning corrections. That's a bold statement, I know...

Let's Summarize

In this five-part series, we went over all the guidelines to properly manage and optimize the bass frequencies of your home theater or listening room. We covered room acoustics, seating positions, speaker and subwoofer selection and placement, and the all-important advanced tuning steps that tie it all together. I know that it got pretty technical, but I had a lot of explaining to do! I hope you got some good nuggets from all this information, and that you can go on to achieving that smooth, loud, punchy and dynamic bass that your system is capable of delivering. Do a lot of experimenting, and remember to **enjoy the ride!**

PS: Here are pictures of Room 1, one of the most bass-challenged rooms I have ever worked in, with proper bass management; it now kicks you-know-what!

measurement mics

measurement equipment

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