DIY Subwoofer Calibration

By

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One of the most profound things I've learned about room acoustics is that nothing happens without a scientific reason. This means that the laws of physics are not, in fact, suspended just to confuse me as I struggle with the calibration of a home theater. This little piece of information has given me great confidence while wrestling with poor sounding rooms thru the years. This was especially comforting when dealing with very exasperated clients who were convinced they had been sold a defective product. One of the themes I touch on during the Home Acoustics Alliance (HAA) seminars is the rule that you are not supposed to chase your tail. In the case of subwoofer location, not chasing your tail means that while certain sub placements might help improve your sound, always seek to understand why your adjustment changed things. Otherwise you will be doomed to repeat your calibration adjustments back and forth. One change improves the sound in one way, meanwhile degrading the improvements of a previous adjustment and so on. If you don't understand the science, your calibration process becomes random and often self defeating.

If the challenge of calibrating your speaker placement by trial and error seems a little daunting lets go to the science and try to decode a practical process. We'll concentrate on the subwoofer but these principles hold true for any speaker capable of reproducing bass. There are many physical effects found in a small home theater that can distort the quality of sound. The most pervasive for subwoofers is usually the phenomena of room modes. Room modes are caused by the resonance of specific frequencies of sound within the boundaries of your listening room.

The effect of resonance is best contemplated by real world examples. The famous collapse of the Tacoma Narrows Bridge in 1940 comes to mind, but this article isn't about bridge design. In the case of sonic resonance the usual impact is not nearly as disastrous but certainly as perplexing. I'll save my technical dissection of sound resonance and room modes for another day. Suffice it to say that the wavelength of a sound wave is the deciding factor on whether a certain frequency will resonate or alternately, if it will just randomly decay without any particular tendencies in a room. Room modes are simply a name we give to the frequencies of sound that resonate. A room's distortion of overall bass smoothness is mostly caused by how it selects only certain frequencies, room modes, to be louder or softer (depending on room location) than the rest of the bass. If we were able to see the real time analysis of the bass in a room as measured from our listening chair it might look like figure 1.

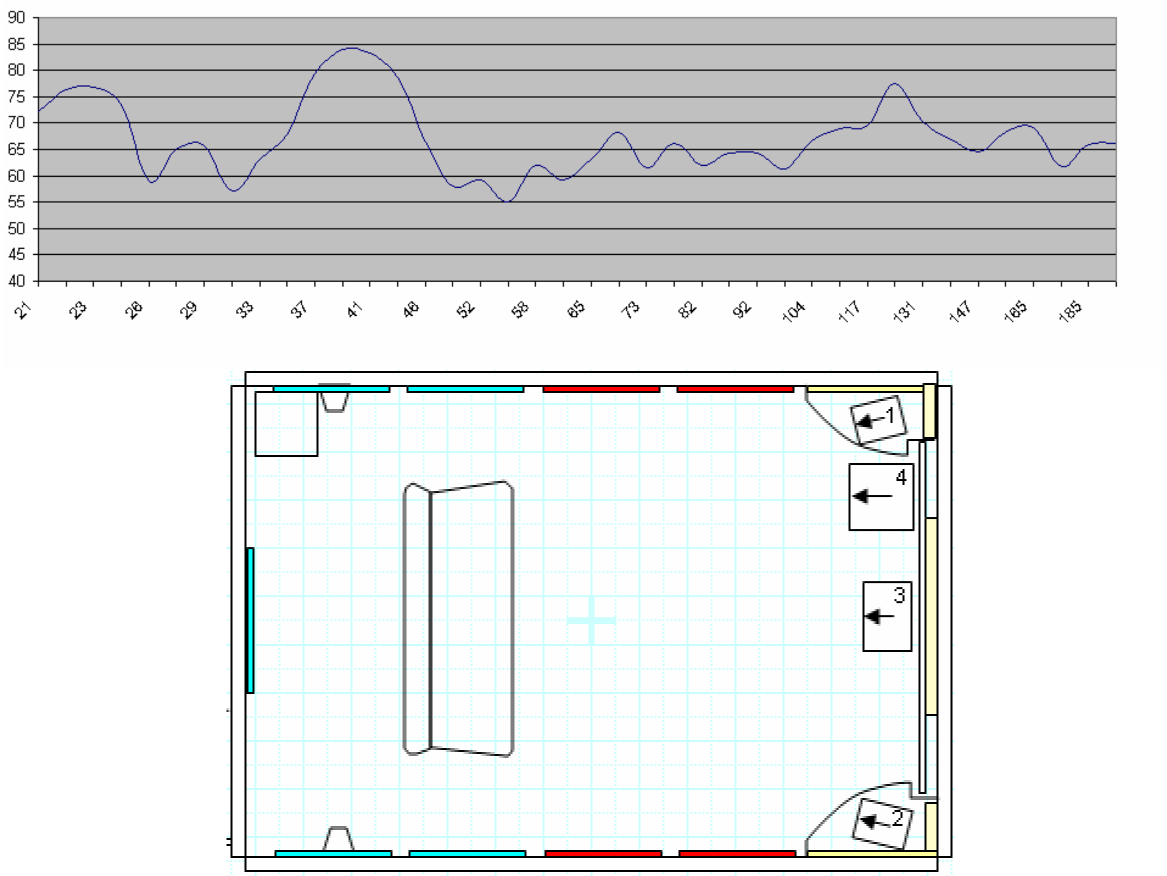


Figure 1

The plot shows a very uneven response with a peaking of sound energy at around 40 Hz. We would hear this peak as a boom or roar effect coloring the response of our soundtrack. This is also the cause of many “turn it down” requests. The accentuation of sound at this frequency is not in the script and is annoying. How do we deal with it?

First, why is this happening? Obviously, this effect is due to a room mode. The room where this measurement was taken has a length of about 14′ 5″ . By using a tidy formula we can predict what frequencies will become modes (for simplicity, we’ll only deal with axial modes; these are the most problematic kind)

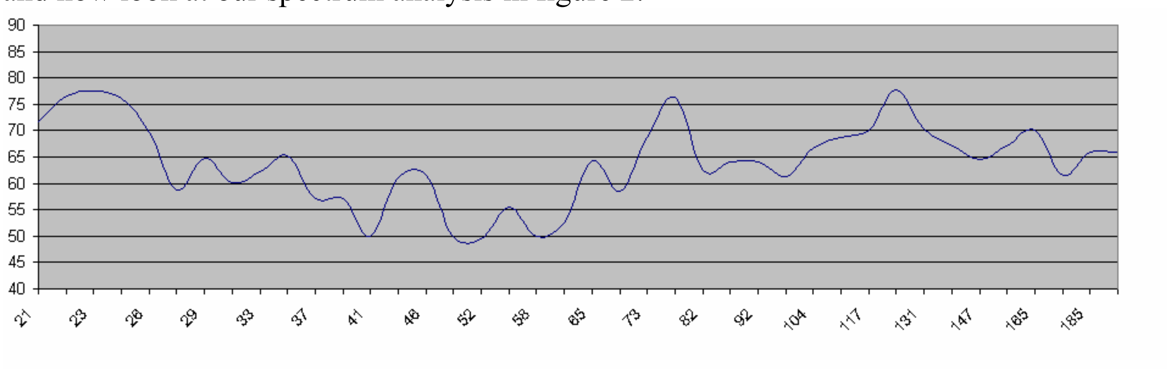
Room mode frequency = speed of sound / (2 times the rooms dimension)

Plugging in the speed of sound as 1130 feet per second and the 14′ 5″ length of this room we learn a room mode will occur at ta da: 39.4 Hz. So how do we rid ourselves of this pesky response distortion? The mode is caused by the timing of the opposing wave trains bouncing back and forth between the front and back walls of this room. If we precisely adjust the timing between the opposing waves (waves moving forward versus waves moving backward) to cease stimulating resonance, we should be able to lose the 40 Hz err 39.4 Hz boom. How do we do it? It’s actually very simple. We move the subwoofer a distance of ¼ of the modes wavelength from either of the walls causing the mode. In the case of this length mode; the front or back wall.

Ok, so now I need to calculate one quarter of the wavelength in order to find out how far to move my sub? Relax it's really just a variation of the formula above:

Distance from wall = speed of sound / (4 times the room mode frequency)

For you math hobbyists you'll note that the wavelength is equal to the speed of sound divided by the frequency. We just took ¼ of that; a quarter wavelength. We move our sub, in this case 7′ 3″ from either the front or back wall (hey isn't that halfway into the room?) and now look at our spectrum analysis in figure 2.



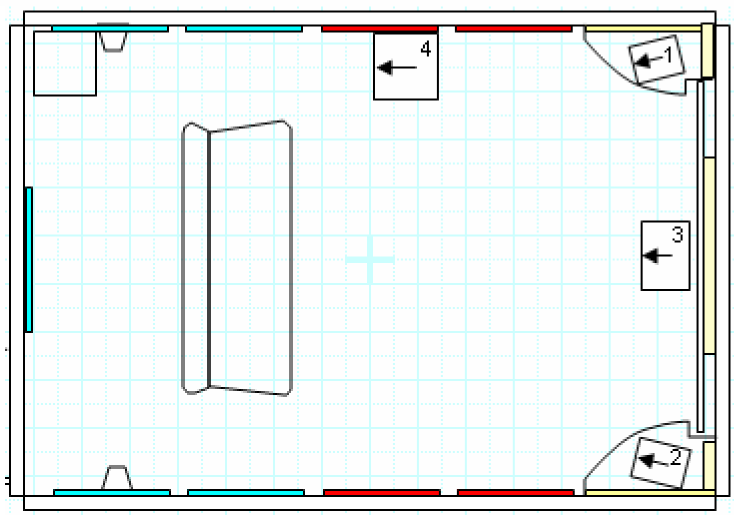
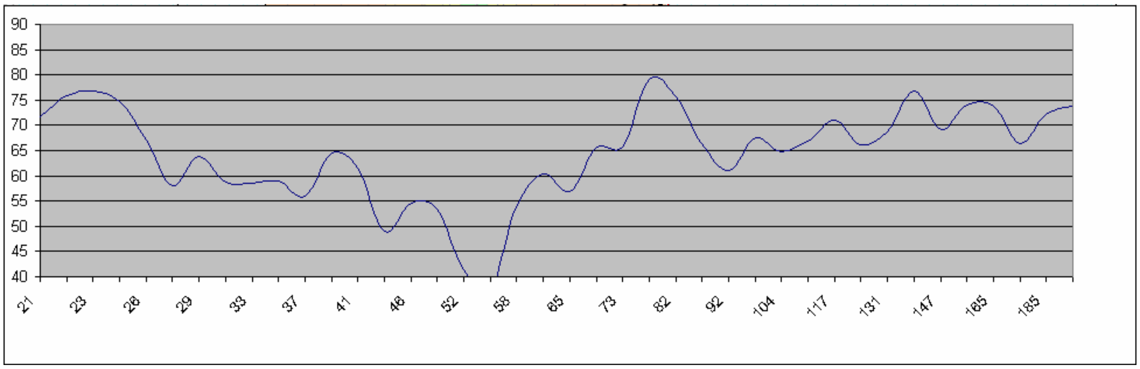


figure 2

Wow, we really cleaned house at 40 Hz! Now before everyone starts moving their subwoofers to halfway down the room's length wall, remember your room is different. And this process is dependent not only speaker position but also on listener position. Room modes are peaks at certain frequencies but they can also be dips in response as well. This depends on where you are in the room. This is where the next technique to eliminate a problem mode comes in; moving the listener instead of the sub.

Let's look at the room used to generate the plot in figure 1. We know the large peak was caused by a length mode. Resonance also implies that in some areas cancellation will occur. We call these areas of cancellation, nulls. You can see from figure 3 how well organized these nulls and peaks appear in a symmetrical room. Notice how the yellow/green colors, depicting a null area, are centered lengthwise between the front and back walls while the peaks (red/oranges) are found against the walls. If you didn't want to hear a boomy 40 Hz tone you could move closer to the null. This would work very well for 40 Hz, but we need to understand the effects of other modes as well.



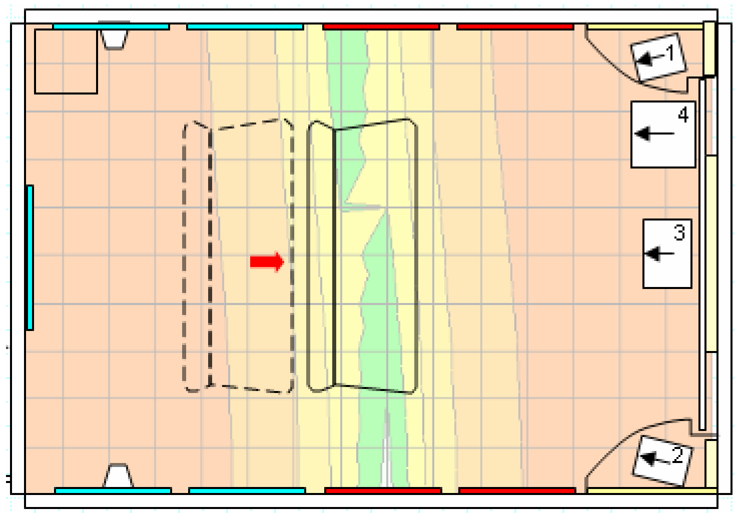


figure 3

Lets looks at a sideways picture that shows the location of the first four length modes of a room, figure 4.

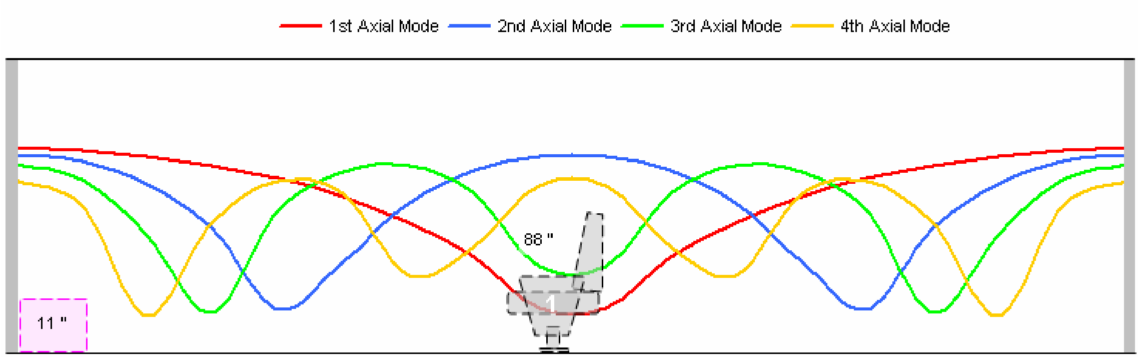


figure 4

You can see the first length modes (in red) amplitude is high near the walls but nulls out in the center of the room. Now look at the next length mode shown in blue (twice the frequency of the first or about 80 Hz). It has two nulls and three peaks. This is your road map toward proper listener placement in a small listening room. You'll note that each mode's frequency is a multiple of the firsts. Thus mode two = 2 times the first, mode three equals 3 times the first and so on. You can use the location of nulls as a tuning mechanism to reduce a particular problem mode. By the way, this is also true for width modes allowing the same kind of adjustment strategy. While it is true for height modes as well, we don't have the same kind of flexibility in adjustment. Have you seen any theater chairs built like barber chairs lately (with up and down lifts)? Luckily if your room is 8 foot or so the first height mode is very close to being beyond the response of your subwoofer any way.

A thoughtful examination of these sound amplitude variations would reveal you should sit in the "moderate zone" for modes. This is found near the intersection of the first and second modes amplitude or about 3/5 of the length and 3/5 of the width (look where the blue and red amplitude lines cross in figure 4). Here we would expect most modes to be neither too loud nor too soft. That would put the best bass chair slight off center and slightly behind the center of the room. We'll discuss the sweet spot controversy in another article; good thing we've got a center channel.

If you are still contemplating moving your sub to eliminate a problem mode you'll be gratified to learn that the location of nulls as shown in figure 4 exactly corresponds to the ¼ wavelength point we discussed earlier. Yes, you can fine tune the response of your system, eliminating modal peaks by moving the sub to the corresponding null for that mode. The locations for nulls of the most problematic modes in a small listening room are at the ½ length or width points, and the ¼ length or width points (null locations for the first and second modes). With out the benefit of a Real Time Analyzer to tell you what the frequency of a peaking mode is, you'll be moving the sub to these positions judging success by using your ears.

There is no way to over emphasize how much easier this process is with a Real Time Analyzer. You can find dealers who own and use such tools on the HAA website at www.homeacoustics.net. If you use music to calibrate your sub, try to use cuts that have a wide variety of deep bass tones. Your appraisal of the evenness between tones will be your yardstick. Also drums can be very good at revealing booms because, while drums are tuned to certain notes, they generally produce a very wide range of frequencies in the bass. Other avenues include using certain test discs that employ warble tones or 1/3 octave pink noise. You can see the relative amplitude of different frequency ranges using your SPL meter. Your target will be to see equal levels (or close) from all frequency ranges.

You can use this process to eliminate or moderate the effect of any problem mode if you understand what its frequency is and therefore can calculate what the wavelength is. Of course the biggest consideration is whether or not you'll be able to set a subwoofer at the best location for listening or move the listener to a moderate zone. For small rooms the modes that cause these annoying peaks are usually scattered below 300 Hz but for subwoofers we thankfully can narrow that range to under 80 Hz. This is not an endeavor for wimps so take some time and have fun. And don't chase your tail!