Subject: Woofer size for uniform directivity loudspeakers
Posted by Wayne Parham on Thu, 10 Jun 2010 18:07:14 GMT
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Personally, I wouldn't go to a 10" driver. In my experience, there is too much midrange off-axis, and it makes a bad directivity match. Also, they usually don't have high enough sensitivity for my tastes unless tuned as a dedicated midrange. For these reasons, I generally don't like going smaller than a 12" midwoofer in a matched-directivity two-way loudspeaker. I'm talking about matched-directivity two-way speakers with 90°x40° to 90°x50° patterns, to be more precise.

To give a little more explanation, consider the way a directivity-matched two-way loudspeaker works and the conditions they are used in. The main objective is to provide a uniform reverberent field, one with good spectral balance. Probably the most annoying abberation is the one that's most common, where there's too much midrange energy in the room. This is caused by having too wide a pattern in the midrange, and the reflected energy adds to the on-axis energy. It sounds something like a bathroom echo, that artificial extra presence you get. In some rooms, it's just a little annoying, others, it can be downright harsh. In the worst case, it can make vocals almost unintelligible, with all the high-level midrange reflections bouncing off the walls, delayed by the extra flight time. So we really don't want to have too much midrange off-axis.

I think this is why I prefer larger midwoofers, because they start getting directional in the upper midrange. They have a little bit of rising response on-axis, starting around 500Hz. The rising response on-axis is due to collapsing directivity, and this also creates falling response off-axis, a pattern that forms a 90° cone around 1kHz. To me, that's perfect, because the 1" compression driver horns are easy to work with in this range, and have physical dimensions that allow close center-to-center spacing for an attractive forward lobe with vertical nulls spaced pretty far apart. It all comes together.

There's another consideration too, and that's related to driver sensitivity. This isn't totally set by radiating area, as other factors come into play. You can modify impedance, for example, to modify (voltage) sensitivity, to set the SPL of a speaker at a given drive voltage level. But radiating area is definitely one of the key factors.

I think the best approach for this kind of speaker is to match sensitivities of the drivers as well as matching their directivities. In terms of voltage sensitivity, it's not a direct match that is sought, but rather approximately a 10-to-1 ratio. We want the CD horn to be 10dB louder than the direct radiating midwoofer, because we need 10dB of compensation for mass rolloff. So a midwoofer that's about 10dB to 12dB lower than the tweeter is a perfect match, allowing the passive crossover to attenuate the horn, and then remove attenuation in the top octave for compensation.

As long as there is at least 10dB to 12dB greater output from the tweeter, there is "room" to gradually remove the midband attenuation in the top-octave, to provide 6dB/octave boost and not "run out" before 20kHz. Mass rolloff begins around 4kHz, so the first 6dB is reached around 8kHz and the second 6dB around 16kHz. That's perfect. As long as the woofer is 10dB to 12dB lower in sensitivity, you can use this approach.

Of course, you could use a woofer with lower sensitivity. But I generally prefer not to go much further than about 15dB. I defeinitely would not want to go all the way to 20dB. I basically consider 90dB/2.83v/M to be a lower limit. Actually, I don't think I've ever used a woofer lower than 93dB.

Consider the scenario that the tweeter, if having 20dB greater voltage sensitivity than the woofer, is producing the same SPL with 1 watt input as the woofer at 100 watts. Just raising the music program level double or four times, 3dB to 6dB, and now the tweeter is seeing 2 to 4 watts, and the woofer 200 to 400 watts. The tweeter in either case is just loafing along with practically zero thermal compression. The woofer, on the other hand, is probably straining and has entered fairly significant thermal compression. These two drivers definitely are not matched.

Now consider the scenario of the tweeter with just 10dB greater voltage sensitivity than the woofer. In this case, the tweeter is getting one watt when the woofer is getting ten. Raise the music power double, four times, even ten times and we're still looking at just 20 watts, 40 watts or 100 watts at the woofer when the tweeter gets 2, 4 and 10 watts: a 10-to-1 ratio. The tweeters are generally designed to handle 50-100 watts when properly high-passed at a frequency and slope so that mechanical excursion is not the limit. The thermal limit of these devices is usually 50 to 100 watts or so. A good quality high-efficiency prosound woofer is designed to handle 500 to 1000 watts before it reaches its thermal limits. So these are a good match for one another, because their design limits are reached at about the same time.

Woofers with 93dB to 98dB sensitivity, measured half-space at 1M and with 2.83v drive are great paired with horns having 105dB to 108dB sensitivity at 2.83v. The boundary conditions don't matter so much on the horn, because the horn sets the pattern. Up high the midwoofer's pattern collapses beyond that of the baffle but midband, it's set by the baffle and down low, it's set by the room. So I suggest the measurements to compare are woofer on a baffle (halfspace) to tweeter horn either in freespace or on a baffle. These are fairly common standards - most manufacturers publish charts of their woofers when mounted on a baffle.

All that to say, we're looking for midwoofers that provide 93dB to 98dB sensitivity, that have good response up to over 1kHz, slightly rising on-axis due to collapsing directivity, slightly falling off-axis for the same reason, and matching the horn's horizontal pattern in the crossover region.

The crossover should be made where horizontal directivity matches, and should attenuate the horn to match SPL in the crossover region. It should reduce the attenuation at a rate of 6dB/octave above the driver's mass rolloff point. And it should match phase of the woofer and tweeter around the midpoint of the speaker, so the forward axis is approximately centered on the baffle normal.

Doing all these things at the same time is kind of a balancing act, and for me at least, I've been most successful with good quality high-efficiency 12" and 15" prosound midwoofers.