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Subject: The Acoustic Center: How it applies to Loudspeaker Measurements

Posted by [Wayne Parham](#) on Wed, 27 Jul 2011 15:44:49 GMT

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I've seen a lot of misinformation spread around the internet, so I thought it might be helpful to post some links to useful information here. Hopefully this will dispel some myths.

To obtain accurate SPL measurements, one usually needs to measure at a distance and then calculate back to find an effective 1W/1M figure. If you measure too close, the value is usually way off. Also, the distance to a point source determines its delay reaching the listener, because of the speed of sound. So the acoustic center is important for that reason too.

Here are some links with more information on the subject:

A note on the concept of acoustic center, by Jacobsen, Figueroa and Rasmussen

Sound system engineering, by Don Davis, Eugene Patronis (Third Edition)

Far Field Criteria for Loudspeaker Balloon Data, Pat Brown (Syn-Aud-Con)

Comparing Loudspeaker Specs, Rick Kamlet, Pat Brown and Dan Field (Pro AV Magazine)

Also, three AES papers on the subject:

Applications of the Acoustic Centre, Vanderkooy, John, AES:122 (May 2007) Paper:7102

The Acoustic Center: A New Concept for Loudspeakers at Low Frequencies, Vanderkooy, John, AES:121 (Oct 2006) Paper:6912

On the Movement of a Horn's Acoustic Center, Ureda, Mark, AES:106 (May 1999) Paper:4986

Applications of the Acoustic Centre:

"This paper focuses on uses for the acoustic centre concept, which in this paper represents a particular point for a transducer that acts as the origin of its low-frequency radiation or reception. The concept, although new to loudspeakers, has long been employed for microphones when accurate acoustic pressure calibration is required. A theoretical justification of the concept is presented and several calculation methods are discussed. We first apply the concept to subwoofers, for which the acoustic centre is essentially a cabinet dimension away from the centre of the cabinet."

There are so many papers like this, written on the subject of the acoustic center, it's nearly impossible to reference them all. Many of them are on the differences between different cabinet shapes, like rectangular boxes, rounded-edge boxes, spheres, etc. Those shift the acoustic center by diffraction, some putting it pretty far out in front of the speaker. Other configurations put the acoustic center far behind the cabinet. All are frequency dependent, meaning the acoustic center moves with frequency.

I encourage anyone reading this to search for academic papers on the subject. Even a quick Google search turns up a lot of useful information:

Google Search: Acoustic Center Concept for Loudspeakers at Low Frequencies  
The take-away from all this is the mouth or face of a loudspeaker should not be assumed to be its acoustic center. Since precision of the acoustic center position is required for close measurements, it makes sense to measure at a distance so that deviations in the position of the acoustic center have less influence.

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Subject: Re: The Acoustic Center: How it applies to Loudspeaker Measurements  
Posted by [gofar99](#) on Wed, 27 Jul 2011 23:02:03 GMT

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Hi, Good stuff. You should try to measure a pair of ESLs. Under normal circumstances virtually impossible to get good readings. I finally gave up and believed what Martin Logan was saying all along. Room parameters are everything with dipoles.

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Subject: Re: The Acoustic Center: How it applies to Loudspeaker Measurements  
Posted by [Wayne Parham](#) on Fri, 29 Jul 2011 06:46:58 GMT

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Absolutely. At midrange frequencies up, the reverberent field is usually almost as loud as the direct sound. So the loudspeaker's polar response is important, because sound radiating in all directions provides the energy for the reverberent field. You need spectral balance off-axis as well as on-axis for a naturally-sounding, uniform reverberent field. Bass frequencies are completely dominated by the room's modal behavior, so room damping, and the number and positions of woofers matters as much or more than the response curve of any individual woofer. And in between - at the upper end of the modal range, just below the Schroder frequency - from about 100Hz to 300Hz is probably even the most tricky range, the transition region. This is where vocals and fundamentals of many instruments lie, and it is where many of the strongest boundary reflections occur. So the room plays a huge part.

But even in an anechoic environment - like outdoors - measurements can be tricky. It isn't as easy as placing a microphone 1M in front of a loudspeaker face and sending it 2.8V. Even when you measure impedance and set the voltage to provide 1W at the speaker, and even if you're using a perfectly calibrated microphone and measurement system, the SPL recorded will probably not be what you might expect. The reason is the acoustic center is rarely at the face of the speaker.

There are lots of things that affect the acoustic center. Some of those include radiating area, total frontal area, cabinet shape/configuration and in the case of horns, path length and flare profile. Each of these things play a part in determining where the actual sound source location is. And the acoustic center changes with respect to frequency too.

One of the definitions of the acoustic center is "the point where pressure attenuation from the inverse-square law appears to originate." That is be the exact point where sound is the loudest. In a large horn, this can be several feet down the throat. If there is not much taper, it will act more like a plane wave tube, having little or no attenuation along the line. In that case, the acoustic center will be at or near the mouth. But if the horn is large and has ample taper, then the acoustic center will be well behind the mouth, sometimes even behind the cabinet in the case of folded

horns.

I've seen some direct radiating cabinets with acoustic centers in front of the cabinet, I've also seen them be behind the cabinet. Some very large horns with long path length and large mouth area have acoustic centers that are several feet behind the speaker cabinet. So if you measure each of these speakers - even if set to generate the same acoustic power level - if the microphone is placed 1M from the face, the SPL recorded is very different. Likewise, if you set the SPL measured 1M from the face to be the same on each speaker, then the total radiated acoustic power level will be different for each speaker, and each will have a different SPL at some reference point (like 10M) further away.

Take as an example, two loudspeakers: One is a direct radiating speaker with acoustic center at or very near the face at 60Hz. The second is a large horn with 10 foot path length and 10ft<sup>2</sup> mouth area, having an acoustic center that's one meter down the throat at 60Hz. Send both a signal that provides exactly one watt of power. For simplicity's sake, we'll say both are equally efficient, generating 100dB one meter from their acoustic centers. Since SPL can be computed by the formula  $\text{newSPL} = \text{refSPL} - 20 \log(d_1/d_2)$ , we know that at 10 meters we would expect to measure ~80dB (100dB - 20log10), and at 100 meters we would expect ~60dB (100dB - 20log100) from each one.

We can also use the inverse-square law, which says that for each doubling of distance, the SPL drops 6dB. This is actually the same formula, with  $d_1/d_2 = 2$ . So at 2 meters the sound drops 6dB, at 4 meters it drops 12dB and at 8 meters it drops 18dB.

But what really happens?

The speaker with the acoustic center at the face will behave just like that. The speaker with the shifted acoustic center will too, provided you reference your measurements to the acoustic center. But if you reference to the face, the SPL values will be off. The error will be greater at close distances, because the ratio between measurement distance and acoustic center offset is greater at close distances.

For example, take the 100dB speaker with no acoustic center offset, and place the microphone 1M from the face. The measurement reads 100dB. Now measure the speaker that has its acoustic center 1M further away. When the microphone is 1M from the face, it is actually 2M from the acoustic center. It reads only 94dB, because it is already twice as far away. That's a 6dB difference.

Now double the microphone distance from the faces of the speakers. The microphone is 2M from their faces. The speaker with no acoustic offset reads 94dB, because the microphone is twice as far from the acoustic center as it was in the previous measurement. But for the speaker with offset, the microphone is now 3M from the acoustic center. This isn't twice as far from the acoustic center - it is only 3/2 or 1.5x as far. So the SPL reduction isn't as great - just 3.5dB - and it reads 90.5dB.

Double the microphone distance again to 4M from the faces. The speaker with no acoustic offset now reads 88dB. The one with acoustic center 5M from the microphone reads 86dB. The acoustic center offset is causing a 2dB difference at 4M.

Double again to 8M. The speaker with no acoustic offset reads 82dB. The one with acoustic center offset is at 9M, so it reads 81dB. There's only 1dB difference at 8M.

At 10M, the speaker with no acoustic offset reads 80dB. The one that has 1M offset is now 11M away, so it reads 79.2dB, less than 1dB difference.

It isn't that the inverse-square law is violated. It's that the source location is not accurately known or used when calculating the falloff. But by scaling at a distance, the inaccuracy is reduced.

This is why measuring at a distance works well for obtaining SPL values. Even if you do not precisely know the position of the acoustic center, the greater measurement distance scales the error and makes it less significant. An easy way to do it is to measure with 100W at 10M distance. It just so happens that 100W is +20dB and 10M is -20dB, so the SPL value recorded will be the same as the 1W/1M from the acoustic center.