Subject: DI-matched two-way loudspeakers
Posted by Wayne Parham on Mon, 23 Nov 2009 20:38:38 GMT
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Lots of people are experimenting with waveguides and DI-matched two-way loudspeakers these

pleased to see them become so popular. Seems like a good time to look back at some of the concepts that are required to make this kind of loudspeaker system perform best. In particular, I'd like to mention what is required for proper on-axis summing, and consequently to provide a large, clean forward lobe.

The center of the forward lobe is (or should be) where woofer and tweeter are in phase. Their phase relationship is determined by the electrical phase of the crossover, the electro-mechanico-acoustic phase of the drivers and horn and the physical relationships to one another. The physical relationship is set not only by the vertical position on the baffle but also the depth, which sets the distance to the listener, creating a fixed delay.

Each driver is some distance from the listener, which introduces a fixed delay. The electrical crossover and the electro-mechanico-acoustic features set the phase, which represents a delay that changes with frequency. The two things are not the same, but if frequency is fixed, then the phase is also fixed, meaning the delay is too. So at a specific frequency, phase has a fixed delay that can be compared to the fixed delay of path length. Similarly, over a narrow frequency band, phase changes are small and so delay changes are also small. The long and the short of it is crossover phase can be used to sort of offset path length differences over a small audio band, where phase shift is within range. This fact is used when designing crossovers in speakers like these, it is how you set the position of the forward lobe.

If the crossover phase and path length differences combine to bring the sound sources in phase straight in front of the speaker, then you can expect the vertical nulls to line up pretty much where you expect them to be. But if the phase shift is a complete cycle (or multiple cycles), then what is straight in front of the speaker is actually a minor lobe, which is generally smaller than the major lobe. You can sort of get the response to be OK, but the nulls will appear to be abnormally close. So if you're modifying one of our models or building your own speakers from scratch, be careful of that when designing and measuring your speakers.

You can use the Altec procedure of reverse connecting the speakers and looking for a null straight out in front, but be aware that you'll see a null at odd multiples of 180°. Every odd half-cycle shift will create a null. So if the woofer and tweeter are in phase and you reverse connect them, you'll see a notch. But this will also happen if the woofer and tweeter are 360° out of phase - a full cycle shift. Reverse the connections and you'll see a notch. This can sometimes make you think you are in phase when you are really a full cycle out.

Say you set everything up, do the Altec reverse-connection thing to put the notch straight out front, then connect properly and measure polars. If you find nulls aren't where you expect them to be from the CTC spacing and frequency, then there's a good chance there is a full cycle or maybe even a multi-cycle shift between sound sources. Again, if that's what you're seeing, then what's straight in front of the speaker is actually a secondary minor lobe, which is much smaller than the major lobe. The major lobe is probably way off somewhere above or below the speaker. So watch out for multi-cycle shifts due to depth and/or crossover phase. They can be kind of tricky, especially if you're working with relatively wide CTC spacing for the crossover band and are expecting a consequently narrowed forward lobe anyway.

When a secondary lobe is out front, the vertical nulls seem to be too close and sort of shady. What I mean is, you can fiddle with the crossover values, and even small changes that seemingly shouldn't make much difference move a null completely out of the picture but also bring the opposite one view into almost immediately. Secondary lobes are smaller, and the notch at their outside edge seems smaller too. That can make it look like one side has no null but the other seems to be too close. It often looks like one side has a big null that's too close and the other side has a little null or none at all.

A long time ago, I used to meticulously calculate the crossover phase and estimate the electro-mechanico-acoustic phase of the drivers. Now I tend to estimate a little more generally, and rely on measurements for more precise determination. Some quick arithmetic shows the wavelength of 1.6kHz is 8.5" and the wavelength of 1.2kHz is 11.3". So a physical offset of half those amounts will introduce a half-cycle shift, as will a 180° phase shift, be it from electrical crossover or electro-mechanico-acoustic phase from a horn or direct radiator in a box.

Hornresp will show the phase of the horn and box modeling tools will show the phase of direct radiators, so you can simulate the system and include the predicted phase in your calculations. That's what I have done, and then combine the physical offset to estimate the phase of the sound sources. When I begin a new system, I do this initially, and even with measurement equipment, it still is nice to know the phase, at least approximately, to know where to start. Measurements can be used to fine tune the system, changing component values a little bit to slightly adjust the phase to get the position of the forward axis and vertical nulls just right.

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