Subject: Crossover induced cancellation
Posted by Wayne Parham on Mon, 09 Jul 2001 10:47:17 GMT
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The purpose of a loudspeaker crossover is to split the audio band into parts and provide them to the correct drivers. A side-effect of using electrical filters that split the bands is that phase is modified. As long as phase between adjacent drivers is limited to 90 degrees, the sound combines constructively. But once phase grows part that, it begins to become destructive and at 180 degrees, causes complete cancellation, limited only by the amount of coupling between drivers. So if two drivers are in close proximity and out of phase, they will cancel completely.One of the characteristics of a symmetrical second-order crossover is that its pair of outputs are 180 degrees apart. Because of this, speaker designers sometimes reverse the leads of one of the adjacent drivers to prevent cancellation. This is one of the attractions for minimalists that prefer a simple first-order filter. Not only does it require few parts, but the phase shift is only 90 degrees, so as long as the sound sources are equidistant from the listener, summing is constructive.The thing is, most loudspeaker designs only take on-axis summing into consideration. Each sound source is placed equidistant from the listener, usually mounted vertically on a baffle. The crossover is then designed so that 180 degree phase shifts are avoided. This is not very difficult to do, and achieves proper summing on-axis. But what happens when you move off-axis, changing the distance between the sound sources and the listener, is that the sound source that shifts further from the listener now is delayed by a small amount. At frequencies and positions where the delay represents a 180 degree shift, anti-phase nulls appear in the polar response. This is a challenge for loudspeaker designs that strive to acheive uniform response through a range of angles. The speaker has to be given some directionality, and summing has to be constructve through the desired range of radiating angles.

Subject: Phase angles, crossovers and baffle spacing
Posted by Wayne_Parham on Tue, 10 Jul 2001 09:23:56 GMT
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Now would be a great time to revisit some of the issues surrounding crossovers and multiple point sources, which occur in the overlap region of the crossover, for the two adjacent drivers.If two sound sources are stacked vertically, then movement along the horizontal plane doesn't change the difference in distances between the listener and the sound sources. So as long as summing is in-phase on the forward axis, it will be off-axis in the horizontal plane up to relatively wide angles.But movement along the vertical plane changes the distance between the sound sources and the listener, delaying the more distant driver by a small amount. At frequencies and positions where the delay represents a 180 degree shift, nulls appear in the polar response.No loudspeaker system with more than one driver on a baffle can have the two sound sources in phase at all locations and at all frequencies. Somewhere, there is going to be destructive interference. But the idea is to place your anti-phase nulls outside the coverage angle. A clever designer makes it impossible for nulls to form within the wall angle of his horn, or at least uses them to abbreviate the cutoff at the edge of the pattern.That's why I like using asymmetrical horn flares with 90x40 degree patterns. The relatively wide horizontal angle provides a large coverage area. The 90 degree angle works out well for another reason, it matches the narrowing directivity of a large-format midwoofer at around 1.2kHz to 1.6kHz. And the narrow vertical angle matches the null angle from vertical spacing of the drivers. If you space everything right, the nulls form just outside the vertical coverage angle of the tweeter horn. In the crossover region, the nulls set the edge of the vertical pattern and at higher frequencies, the tweeter horn's wall angle maintains the relatively tight vertical control. Axisymmetrical horns won't do this, instead, the vertical pattern will widen back up above the crossover band.It is important to position the drivers vertically where the off-axis nulls are just outside the angular coverage of the horn. The first thing to do is to set the centerline for the forward axis. This is done quite simply by aligning the acoustic centers on the Z axis, front-to-back. I say "simply" in that it is simple in principle, but sometimes rather complex in practice. The reason is the physical position of the drivers may or may not be aligned, because the acoustical load changes its reactivity and both that and the electrical phase of the crossover filters changes the apparent position of the sound sources. The designer must take each of these things into consideration, acoustical reactivity, physical position and electrical phase.Aligning the sound sources on the Z axis sets the forward axis centerline, which biases the arc of in-phase summing in the vertical plane. The nulls that form above and below this centerline are found at angles determined by the distance between drivers and the frequencies where they are both used. When using a horn with 40 degree vertical coverage, it is best to set the arc between nulls around 40-50 degrees through the crossover region, which is accomplished by vertical center-to-center separation on the baffle of approximately 12". Closer spacing makes the null angle wider, and further spacing makes the null angle more narrow.Knowing the acoustic position is important and difficult, but fortunately, if you crossover at 1.2kHz to 1.6kHz or so, wavelength is over 10" long. That means you have a range of about 5" where interaction between drivers causes positive summing and about 5" where it causes cancellation. Actually, I should say 5" where summing "tends towards" positive or negative reinforcement; The fact is, at this frequency range you won't see the notch from negative reinforcement until you're within about an inch forward or back of the position that causes path length to be 180 degrees out of phase. But this, alone, will tell you a lot.Even with crude measurement equipment, you can find this notch. You have decent visibility because the cancellation makes a big hole in amplitude response. You'll have to measure outdoors to make sure what you're seeing isn't a reflection. If you wire up direct and measure straight on axis, then reverse polarity to one driver and see a notch, then you know the drivers are aligned. This also is true if a symmetrical crossover is used. If you don't notice a clear notch when reverse connecting the drivers, then you can move a driver forward or backward a few inches to find the notch. Start first by setting the notch straight on axis, even if it means moving the tweeter forward or back from being flush with the baffle.This is the Altec alignment method, and it works pretty well. You can't know if you're in phase or some multiple of 360 degrees out of phase, but since we're working with 10" wavelength, you can rule out multi-cycle shifts by physical alignment. You may (will) have some offset due to electro-mechanico-acoustic differences, but they won't create anywhere near 10" offset. So as long as you have the physical alignment close in a system like this, you have enough to learn where the center of your arc is.Once you know the acoustic source positions, you know what you're dealing with. If the tweeter has to be moved forward a couple inches for alignment, then moving it back flush to the baffle would shift the vertical centerline upward. You might use asymmetrical slopes or staggered crossover points to shift it back. Higher orders cause more delay, and can be used provide apparent offset. Staggered crossover points change the phase between drivers too, and can be used to shift the null angles.