Subject: Baffle spacing, phase angles and time alignment, revisited
Posted by Wayne Parham on Wed, 14 May 2003 04:56:30 GMT
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In this post, I'd like to revisit the issues of baffle spacing, phase angles and time alignment. It's been a while since we talked about this, and I think it would be good to come at it from a different angle.

Bad pun. Sorry.

There's no way to make two sound sources be phase-aligned at all points in space and at all frequencies. Not even an infinitely powerful DSP algorithm on an infinitely powerful computer can accomplish phase correction of two or more sound sources at all points and all frequencies simultaneously. But a designer can pick their target locations and range of frequencies and align for them. The better products are those that have design choices that limit dispersion and crossover overlap such that anomalous conditions are only present outside the dispersion window, and so are not developed by the loudspeaker at all, or at a highly suppressed level.

The reason for this is simple. When there are two points in space generating a wave, there can be path length differences between the observer/listener and each source. If those path length differences are at odd multiples of a half wavelength, then cancellation results. So there are positions and frequencies that will cancel, resulting in nulls.

The most common solution is to align sources vertically, so that movement on the horizontal plane results in no change to the distances between the observer/listener and each source. That means that the problem will only present itself at certain positions along the vertical plane. I'll provide some illustrations below, which are from the AES Journal paper called "Improvements in Monitor Loudspeaker Systems."

The illustration above shows the window of locations where response will be good for this loudspeaker. Generally, if the crossover region is narrow, one can assume that both subsystems will be online only over a very small band of frequencies around the crossover frequency. Frequencies above or below this region will be generated by only one sound source, but in the crossover region, there will be two sound sources that are separated by space and time (phase). Where the angles between sound sources cause path length differences at odd multiples of a half wavelength, interference nulls are formed. Really clever designs have these nulls positioned at the edge of the coverage pattern, where they actually become useful, serving to abbreviate pattern cutoff.

The normal listening room is wider than it is tall, so the ideal coverage pattern is too. One problem that presents itself is a flare angle that is wider than it is tall terminates in a mouth that is also wider than it is tall. This means either the horizontal flare must be oversized to allow the vertical flare to develop enough to get pattern control, or the horn can be made smaller but it will sacrifice vertical control. However, if the adjacent drivers are stacked vertically, then interference nulls are formed at angles above and below, with the angle determined by the positions of the sound sources. If carefully placed, these nulls will act to reinforce pattern control, by providing it at low frequencies where the undersized horn is not able to provide vertical control solely by its dimensions.

tweeter and midwoofer is somewhat distant for aesthetic reasons. It wouldn't look good to have a large box with two drivers stuck closely together. But there is also some reasoning behind the choices, as is shown by the analysis below.

tweeter-midwoofer spacing of 13.25" yields

d1 = 0.33m (13.25") between the tweeter center and the midwoofer center

a = 19° or 2a = 38° (arc between nulls)

This is equal to the vertical dispersion of the HF horn. The nulls are set at the edge where HF dispersion falls off.

This is my favorite implementation, and why I prefer asymmetric horns to round or square ones. Not only is the target listening area asymmetric, but the vertical placement of sound sources tends to work in your favor if you choose such a pattern. I like a consistent radiation pattern in both horizontal and vertical planes, or at least a uniformly collapsing one. But with vertically stacked sound sources, one must pay attention to coverage angle and driver placement in order to avoid having an off-axis null right in the middle of the pattern. In my opinion, the best way to handle this is to limit the vertical pattern to the location of the first null.

The bottom line is that there are a handful of things to consider when bringing two subsystems together as a loudspeaker system. The slope of the crossover sets the phase relationships of the motors and the overlap frequency region. The directionality, position and orientation of the radiators sets the acoustic phase relationship in space as well as the amount of energy delivered to that space. So if the two radiators are nearly matched in directivity and output in the crossover range, then the transition will be seamless and the reverberent field will be uniform, resulting in the most natural sound.
