Subject: Pi horn design philosophies
Posted by Wayne Parham on Tue, 01 May 2001 03:46:15 GMT
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Pi Speakers are best described as high-efficiency, controlled directivity loudspeakers. They've always used high-efficiency drivers like those from Eminence and JBL. They evolved from my early designs concentrating mostly on flat amplitude response to having more controlled directivity and consistent response within the intended coverage angle.My earliest speakers were simple bass-reflex cabinets with direct radiators, two-way for small systems and three-way for larger ones. I put most of my attention on finding cabinet alignments that gave smooth bass response, and designing crossovers that worked well on-axis. The cornerhorn was an attempt to use the room corner as an advantage, much like Klipschorns do. But I wanted a speaker that was simpler, both because it is easier to build but also because I didn't like the sound of midrange going through the basshorn like it does in the Klipsch design.The cornerhorn quickly evolved into a uniform directivity experiment. I noticed right away that the Pi cornerhorn did something special, even when loaded with only direct radiators. I built them in several varieties, always with a rear-facing woofer but some with mid and tweeter in front, some with mids and tweeters in front and back, others with mids in front and back but tweeters in front only. I also experimented with different driver sizes. What I learned was that the cornerhorn speaker could be made to produce a wide, smooth sound field with the right combination of position and sizes of drivers. As I continued to study and experiment, I came to the conclusion that what it was doing that was so special was to provide a uniform reverberent field.
Getting a uniform reverberent field requires having flat power respsonse. The total sound output on all axis be equal in amplitude. It doesn't have to be omnidirectional, in fact, it is better that it is not. Omnidirectional sound sources suffer from early reflection interference problems. The best speaker is one that combines controlled directivity with uniform polar response. It directs the sound towards the listeners within the room, rather than bouncing sound off the walls, floor and ceiling. The sound in any direction has uniform spectral balance, although the volume level within the pattern is much louder than at the edge of the pattern, and outside the pattern it should not be loud at all. This is the goal.The Pi cornerhorn tended to naturally obtain much of this goal, because sound is constrained by the walls, even when driven by direct radiators. The angular coverage of a direct radiator is very wide at frequencies where it is acoustically small, and it narrows only at high frequencies when it becomes large with respect to wavelength. So a uniform reverberent field is practically ensured. However, early reflections are also ensured ffrom direct radiators so more directional sound sources at medium and high frequencies is a better solution.As I realized the importance of directivity and I started using constant directivity horns exclusively. I chose a 90x40 flare because it roughly matched the wall angle of the cornerhorns, and because it was a useful angle for room coverage from a stereo pair of speakers. I also began to build what I call DI-matched two-ways, which use a large midwoofer up to the point where its directivity collapses to match that of the tweeter.There are a couple of challenges that face the designer of a constant directivity speaker with compression horns. One is compensating for the power response of the drivers. The other is proper summing between adjacent sound sources through the crossover region through the arc of the desired coverage angle.Dealing with the problem of power response compensation, the idea is to identify the power response and provide electrical EQ that is the conjugate of that. If directivity is constant, then the amplitude response anywhere in the pattern is the same as the plane wave tube of the compression driver. What the crossover needs to do is provide a conjugate of the driver's power response. In other words, it must provide electrical EQ for the driver.A 1" exit compression driver is generally flat to 3kHz or

4kHz or so, and then falls off at 6dB/octave, except in cases where diaphragm breakup creates peaks and notches along this general trend. The conjugate filter, then, is a shelf of flat response, followed by 6dB/octave augmentation above 4kHz or so. This is fairly easy to do with passive RLC networks, and is done very nicely in the Pi crossover.Getting proper summing is a matter of finding the angles where path length differences will cause anti-phase cancellation, and limiting the radiation pattern to angles smaller than that. 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.