Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Sun, 29 Jul 2012 15:40:04 GMT
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Thanks for your kind words.  If you're interested, some of the history is described in the following links:

High-Fidelity Uniform-Directivity Loudspeakers
Pi horn design philosophies
Corner pi speakers

My personal opinions of various design philosophies
As for the development of the H290C in particular, I had initially been attracted to the quadratic throat waveguide, as it resembled radial horns which I had empirically found to provide the best performance.  Then later, after discussing oblate spheroidal waveguide/horns with Earl Geddes, and then upon finding the documents below about Gaussian wave propogation, as well as many other texts on similarly related topics, I was convinced this flare profile made sense.
Landesman dissertation about wave propogation based on the Oblate Spheroidal coordinate system
Landesman Paper about the OS coordinate system
An explanation of the paraxial approximation, which is relevant to this discussionConoidal surfaces are defined by lines drawn tangent to an oblate shperoid.  The resulting curve is a hyperboloid of one sheet whose asymptotes pass through the origin (x/y axis) inclined at an angle cos-1 with the z axis.

You will notice on page 73 of the first paper above, equation 4.2 is the formula used to plot this flare profile, the one commonly referred to as describing an oblate spheroidal (and/or elliptic cylindrical) waveguide/horn.  It forms a hyperbola created from a line drawn tangent to an oblate spheroid or elliptic cylinder.  The two are the same profile, but the OS is round while the EC is rectangular.  The two can be joined easily, since they are based on the same family of elliptic coordinate systems, allowing for a smooth transition between round throat and rectangular mouth of whatever aspect ratio is desired.

I have also used a polynomial expression to plot this flare profile, one that tracks the trigometric function precisely, but it is a more complex formula.  I did it purely as a curve fitting exercise.

These are the equations used to describe the H290C waveguide/horn:

What is not shown by these formulas are the mouth radius and the profile at the edges.

The mouth radius is borrowed from LeCleach, in that it is a gradually increasing angle calculated using an iterative approach.  But it is not a large part of the total profile so in truth, it could have been a tractrix or some other shape, even an arbitrary radius.  I just wanted to avoid any sharp edges.

Similarly, I wanted to provide smooth features on the diagonals, but also to maintain as much of the area as possible, which is why I chose a rectangular profile. I think the super-ellipse would have been fine too, but I saw no reason to take that shape, so what I did was to use the same formula as shown above and apply it for the oblique angles, but just enough to provide a round entrance that gradually blends the sides with top and bottom so that the exit is rectangular.

The end result is a shape that has slightly wider tangential angles on the diagonals. The profile starts off round, then slowly changes to elliptical, then towards more of a super-ellipse, then finally to a rectangular exit. But the profile at every point - horizontal, vertical or obliques - is described by the trigonometric formula above.

My design goals were to create a device that had uniform directivity but not at the expense of response smoothness. I also wanted an asymmetrical flare, because I like the ability to minimize the vertical spacing of MF and HF sound sources.

I always though that discontinuities inside the horn caused response ripple due to impedance spikes. They also cause diffraction, which may be useful for widening the pattern but it destroys imaging. So waveguides are attractive in that they limit these problems, but many of them aren't so good at acoustic loading, and so suffer from response ripple. I wanted the best of both worlds, and I found that it is possible, provided you design the waveguide paying attention not only to flare profile but also area expansion and length.

The asymmetrical flare prevents ceiling slap at high frequency, which I find very useful. It also allows close vertical spacing, which then provides a nice, tall clean forward lobe. And it has a side benefit, which is that it doesn't have a huge on-axis dip from mouth reflection like round horns do. I wouldn't want the loudest radiation angle to have a lot of ripple, and asymmetrical mouth mitigates this. So the vertical nulls are widely spaced, and there is no on-axis null. I find that much more attractive than having large nulls on-axis, as well as slightly above and below the speaker, like round horns have.

I've heard it said that the oblique radiation from a elliptical or rectangular waveguide is abnormally wide. This is true. But I find this to be completely acceptable, especially in light of the fact that this very feature makes the forward lobe so nice and tall. I think it is weird to look at the obliques, when the verticals are more important. Fix those first. Nulls out at oblique angles are usually pretty fuzzy, and I just don't see a problem there.

I've also heard it said that an asymmetrical horn has less vertical pattern control, or that it gains control only at higher frequency, the so-called pattern flip thing sets in. This is also true. But what I tend to see in most of these ~90°x50° waveguides is that they haven't "flipped" at the ~1kHz crossover region, they're basically doing 90°x90° there. The horizontal is in control, and vertical isn't yet, it is still collapsing up for another octave or so. The vertical nulls are usually around +/-25° if the speaker is well designed, so the forward lobe is clean, about 50° tall. Within the next octave or so, the horn gains vertical control and limits beamwidth to 50° for the rest of the range. So I think that's a pretty good paradigm.

Another thing that is attractive is the asymetrical mouth shape allows the area exapansion to be less than what it would be from a asymmetrical flare having the same horizontal angle. This is useful for acoustic loading.  This is the best waveguide shape for my loudspeakers, and in my opinion, is the best waveguide shape for any speaker that is to be used for home hifi.  It gives the smoothest response possible, low diffraction and well-behaved uniform directivity.