Subject: H290C Horn/Waveguide
Posted by santos on Tue, 27 Mar 2012 08:48:33 GMT
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Wayne, I can't find H290 in Europe. Is there an alternative without having to change any thing in the crossover. I already have your 4 pi crossover at home and I'm not handy enough to change any thing.
Thank you
Santos

Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Tue, 27 Mar 2012 12:55:03 GMT
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There is no suitable alternative to the H290, now designated H290C. The horn/waveguide properties are very specific, and it cannot be substituted without a complete redesign/test cycle. The biggest issue is the position of the acoustic center, which is affected both by the acoustic load and the depth of the device. The size and shape of the H290C are precisely set to provide the right beamwidth, loading and acoustic center.

The problem many people are facing is that Eminence discontinued the H290 horn. They were getting them from an overseas supplier that has stopped making them. We are now making the H290C horn/waveguide - and in fact, have updated the profile to have an oblate spheroidal flare profile. It is essentially a plastic version of the wood horn we've been making for years, so we could leverage the design work we've already done.
Horn/Waveguide dimensions and beamwidthSo my suggestion is to purchase the horns from us. There are other suppliers that still have the H290 in stock, but it is rapidly dwindling. Besides, our new H290C is an improved device, one that can be considered an upgrade. It uses the same baffle cutout and mounting holes, so it's an easy bolt-on replacement.

Subject: Re: H290C Horn/Waveguide
Posted by Maxjr on Thu, 29 Mar 2012 18:26:01 GMT
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Wow! Wayne, that new H290C waveguide looks great! I wish I new about these prior to purchasing the Eminence H290 units. From a layman's standpoint, what are the noticeable audible differences between the H290 and H290C?

Cheers!
Joel

Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Thu, 29 Mar 2012 19:22:47 GMT
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The original H290 was a pretty good device, so you shouldn't feel like you've been left in the weeds. It's what I've long considered a happy accident, in that it had very good polars and sounded great in spite of the fact that the curve of the profile was not oblate spheroidal. But the throat shape was close, and the extra expansion towards the mouth acted as a hedge against narrowing beamwidth at the bottom end. It could have used a mouth radius, but other than that, it was a pretty darn good horn.

Subject: Re: H290C Horn/Waveguide
Posted by skywave-rider on Thu, 29 Mar 2012 23:28:44 GMT
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Order placed.

Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Thu, 17 May 2012 00:19:03 GMT
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The first couple sample H290C waveguides are ready for me to check. They look good, but they need to be measured (physical dimensions) before we go for the full production run. I may have them verify some measurements at the mold shop before even sending, but from what I can see, they look great. So we're getting close.

Subject: Re: H290C Horn/Waveguide
Posted by Maxjr on Thu, 17 May 2012 21:37:32 GMT
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Wayne,

Will these be a bolt in replacement for those of us who have already built our 4Pi cabinets? I

already love my 4Pi's so much (thank you, again, for a superb design!) but have an awful habit of always upgrading (cars, speakers, etc.)  It must be the perfectionist in me.

I'd like to sell my original H290 cheap and replace them with these.  Also, do you know approx when you'll receive the production units that will be ready for consumer purchase? Thanks!

Cheers,
Joel

---

Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Thu, 17 May 2012 22:05:07 GMT
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Yes, the H290 horns in existing designs can be retrofitted with H290C waveguides.  It was designed specifically to be a bolt-on upgrade.

The old H290 was really pretty good, acting much the same as a waveguide providing nearly constant horizontal directivity and low diffraction.  The most important feature I had to maintain was the position of the acoustic center, and the new H290C has the exact same acoustic center in the crossover region.

I expect to have inventory in six to eight weeks or so.  We already have taken several preorders, and in fact, I may have to up the initial order quantity.  No problem though, the molds are good for at least a million units.

---

Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Fri, 18 May 2012 03:52:32 GMT
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More photos (click on photo for a close-up):

Subject: Re: H290C Horn/Waveguide
Posted by skywave-rider on Fri, 25 May 2012 19:50:58 GMT
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They look great, Wayne. Take your time.

Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Thu, 12 Jul 2012 13:08:35 GMT
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Measurements

all measurements taken using DE250 driver
mounted on infinite baffle, i.e. half-space
drive signal 8.4v
microphone distance 3M

Impedance

also see it in the response curve below.

dimensions of the H290C place that peak just below the passband, which I find an attractive configuration.

Its pure oblate spheroidal flare profile sets its length and mouth size based on its tangential wall angle and throat size. These are fixed dimenisions, set by its geometry, as discussed earlier in this thread. A conical or OS flare has to be at least as long as half its width to achieve the right mouth size to support a 90° pattern. You can't create a right triangle with any other dimensions.

On-axis response

Devices like this have a peak at cutoff, followed by reduced output through the first octave. That's because they don't really provide good acoustic loading down low. They start becoming most

region, as well as for setting the top-octave compensation for mass-rolloff. The values chosen for

virtue of attenuator bypass capacitor and/or shunt resistor and the rising impedance of the voice coil). So this very versatile crossover configuration is perfect for waveguides.

Horizontal Response Curves, every 10° through a 180° arc

Horizontal off-axis response is excellent, very uniform through the coverage pattern, and well-behaved outside the pattern too.

Horizontal Contour Chart (Directivity Sonogram)

Viewing the horizontal beamwidth using a sonogram, you can see that energy distribution is very uniform. However, you may also notice that at low frequencies, the beamwidth doesn't widen as you might expect, it actually becomes more narrow. This is called waistbanding, a narrowing of the beam before the pattern widens at low frequencies below 1kHz.

The H290C waveguide is optimized to reduce internal reflections through the passband, and to do this requires the oblate spheroidal flare profile remain pure, without much of a secondary flare widening at the mouth. This approach trades a slight amount of waistbanding for reduced internal reflections, smoother response and improved overall sound quality.

This is a useful tradeoff because waveguide beamwidth narrows in the crossover overlap region where it blends with the other sound source. The two sources contribute to the overall summed response in all axes, and this provides the loudspeaker designer an easy solution path for uniform directivity.

The chart above shows the energy produced at all horizontal angles without normalization. Being denormalized, you see the actual energy distribution at various angles, not the directivity as referenced to the on-axis level. If we want to see that, we must normalize the curves to the on-axis chart, as shown below:

Horizontal Contour Chart (Normalized to the on-axis curve)

This shows directivity is constant through the passband. The definition of beamwidth is angles where the SPL is -6dB from the on-axis level, which can be seen to be constant at 90° (+/-45°).

It is easier to see the -6dB points if we stratify the contour gradient at 6dB rather than every 1dB. This shows the beamwidth angles very clearly:

Horizontal Contour Chart (Stratified at 6dB increments)

Now to the verticals.

Vertical Response Curves, every 10° through a 180° arc

Naturally, the output at large off-axis angles is reduced considerably in the vertical. This is exactly what we want. It cannot maintain directivity control all the way down to 1kHz like it does in the horizontal axis - the horn is too small in the vertical dimension. But it is able to start gaining directivity control around 2kHz, which is excellent for a horn of this size. It also manages to collapse directivity gracefully, largely due to the mouth roundover and baffle mounting.

As you can see, directivity smoothly collapses as it begins to get control around 2kHz. By 3kHz, it is around 50°, and it remains pretty constant above that point.

Vertical Contour Chart (Directivity Sonogram)

Again, we are viewing the energy produced at all vertical angles without normalization. Being denormalized, you see the actual energy distribution at various angles, not the directivity as referenced to the on-axis level. If we want to see that, we must normalize the curves to the on-axis chart:

Vertical Contour Chart (Normalized to the on-axis curve)

This shows vertical beamwidth is constant from 3kHz upwards through the passband. Again, the definition of beamwidth is angles where the SPL is -6dB from the on-axis level, which can be seen to be constant around 50° (+/-25°).

It is easier to see the -6dB points if we stratify the contour gradient at 6dB rather than every 1dB. This shows the beamwidth angles very clearly:

Vertical Contour Chart (Stratified at 6dB increments)

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Subject: Re: H290C Horn/Waveguide
Posted by skywave-rider on Thu, 12 Jul 2012 15:30:52 GMT
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Tour de force.

---

Subject: Re: H290C Horn/Waveguide
Posted by zheka on Sat, 28 Jul 2012 00:58:07 GMT
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Wow!

Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Sat, 28 Jul 2012 17:13:55 GMT
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Thanks for the thumbs up, guys.  I'm really proud of it.

As many of you know, but some probably don't, this H290C horn is a molded plastic implementation of a horn I developed about ten years ago.  It's the horn shape I always wanted.  For many years, I've used horns that were close, mostly because they were available and gave me 95% of what I wanted.  But this is exactly the right shape, without compromise.

My first go at a no-compromise horn/waveguide was what I now call the H390C.  I made it out of wood, and it is as much aesthetically beautiful as it is acoustically correct.  The thing is, since it is designed to be cradle mounted, it doesn't have the benefit of the baffle, and therefore had to be made a little larger.

This H290C is the exact same shape as the H390C from throat to about 70% the length of the horn - It has the OSEC (oblate spheroidal / elliptic cylindrical) flare profile in both horizontal and vertical planes, and also in the transition at the edges between them.  This shape allows the wavefront to transition perfectly from the plane wave generated by the compression driver into a section of a sphere at the mouth.  This transition from plane wave to spherical wave is one of the most important functions of a horn/waveguide.

The biggest difference between the H290C and the H390C (besides material) is the radius to the mouth.  The H290C doesn't need as much of a radius, particularly in the vertical.  The baffle provides some assistance here, reducing the size requirements.  That is a welcome feature, since reduced vertical size allows center-to-center spacing between sound sources to be made smaller, increasing the size of the forward lobe.  That has always been important to me.

This horn has been a long time coming.  It really is the latest evolution of three decades of work.  There are other waveguides out there, some from relative new comers, others from experts in the field.  But none of them are as good as this waveguide, in my opinion.  This one is the exact right shape and size for what we're trying to do.  It's the horn I always wanted.
Notes for the DIYer

Subject: Re: H290C Horn/Waveguide
Posted by zheka on Sun, 29 Jul 2012 13:32:41 GMT
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Thank you.

By the way, I personally like knowing the background and historical perspective, the maturity from

long evolution of your designs. There's a lot more here than just a waveguide. Perhaps one day you can find a good place to write it.

Thanks again for taking time respond.

Cheers!

---

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.

---

Subject: Re: H290C Horn/Waveguide
Posted by mantha3 on Tue, 31 Jul 2012 16:17:11 GMT
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These look really nice.. I have the Eminence H290 with the B&C DE250. Those DE250s are heavy!

I like how the Eminence horns have the bolted plate you mount the compression driver on that reinforces the plate to the horn. The plate you bolt the driver to... Do you worry about that plate breaking free from the horn?

---

Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Tue, 31 Jul 2012 18:17:47 GMT
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That is an important joint, certainly. Ours is extra thick there, and is a one-piece design. The mold was more expensive, but it makes the horn seamless, being a one-piece part.

---

Subject: Re: H290C Horn/Waveguide
Posted by mantha3 on Tue, 31 Jul 2012 19:28:04 GMT
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I have the Eminence horns... I have not started the build. I can't return the horns I have... Tempting to buy yours anyway.

Shoot!

Subject: Re: H290C Horn/Waveguide
Posted by skywave-rider on Tue, 31 Jul 2012 20:10:36 GMT
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I have to say, it looks sharp. That's not really important, but nice.

Wayne Parham wrote on Tue, 31 July 2012 13:17
That is an important joint, certainly. Ours is extra thick there, and is a one-piece design. The mold was more expensive, but it makes the horn seamless, being a one-piece part.

Subject: Re: H290C Horn/Waveguide
Posted by blvdre on Tue, 31 Jul 2012 20:35:11 GMT
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mantha3 wrote on Tue, 31 July 2012 14:28I have the Eminence horns... I have not started the build. I can't return the horns I have... Tempting to buy yours anyway.

Shoot!

I was able to sell mine on the parts express forum. Give it a shot, maybe you'll get lucky.

In other news, my new H290C horns are on their way

Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Thu, 09 Aug 2012 15:38:12 GMT
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Some have asked why it is important to maintain 90° beamwidth in the horizontal, and why 100° or more is less desirable. For example, one of our friends here recently evaluated another similar waveguide/horn with ~100° coverage. The other horn was touted as a 90° waveguide, but all measurements pointed to it having at least 100° beamwidth in the horizontal. It became somewhat of a point of contention, with the other horn/waveguide proponents reverting to an argument of "how much does it matter anyway?"

So what is the difference between 90° beamwidth and a little more, say 100° or 110°? What's wrong with a slightly wider pattern in the horizontal? How much does it really matter?

If the speaker were outdoors or in a very wide open space, I would find nothing wrong with the wider pattern. With no boundaries to worry about, I almost don't care what the coverage pattern is. But indoors, in a home hifi environment, the whole point of controlled directivity is to reduce early reflections from the nearest walls. I mean, why bother with having a waveguide/horn at all if your coverage pattern allows a significant amount of energy to be reflected off the side walls?

The sound radiated by a horn/waveguide doesn't end abruptly at the beamwidth "edge". Beamwidth is defined as the angle between the directions on either side of the forward axis, at which the intensity of the sound pressure level drops to one-half the value it has on the forward axis. That's only -6dB down, so sound definitely radiates outside this coverage pattern.

The goals are to provide uniform coverage within the desired beamwidth and to limit radiation outside this angle, to reduce unwanted reflections. So if I were to have to choose between being a "smidge" inside or outside the goal, I'd definitely lean towards being slightly tighter than wider. I'd rather have constant directivity through an 80° horizontal arc than 100° beamwidth for this application.

One shouldn't go too far with this, because too-narrow beamwidth is unnatural too. The square corners of our living spaces make 90° beamwidth a very natural coverage angle. But again, we certainly don't want coverage wider than 90°, because that increases reflections and reduces the benefits of controlled directivity. So I think a good target for horizontal beamwidth is to stay in the 80° to 90° range.

This is particularly important in a constant directivity cornerhorn. The bass bin and midhorn are

horn, a source constraint boundary rather than a reflector. But the tweeter horn/waveguide is

waveguide beamwidth be 90°, matching the angle formed by the room's corner. A wider beamwidth would illuminate the walls and cause excessive reflections.

Even in a matched directivity two-way speaker, the extra beamwidth is unwanted. When the forward axes are crossed, toe-in at 45°, the edges of the pattern run parallel to the adjacent walls, just like cornerhorns but usually a little further away. The wall behind the speakers isn't usually all that far though - often just a few feet - and you really don't want a lot of off-axis energy to reflect off that wall. Using a 90° horn/waveguide ensures that sound directed at this wall is at least -6dB, even at a grazing angle, and more attenuated at larger angle of incidence. So this is the best configuration, in my opinion.
High-Fidelity Uniform-Directivity Loudspeakers

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Subject: Re: H290C Horn/Waveguide
Posted by Maxjr on Thu, 16 Aug 2012 12:42:37 GMT
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Wayne,

I'd like to purchase a pair of these bolt on upgrades and replace the current Eminence H290 horns I have in my fully upgraded 4Pis. I have two questions regarding the new H290C:

1) Are there any changes needed to be done on my current crossovers? I can modify them, no problem. I'm just curious.

2) What audible differences could be expected when I compare the H290 to the H290C head-to-head with everything else remaining the same (JBL driver, crossovers, DE250, speaker enclosure, listening environment, and music)

Thanks for your time and all your efforts!

---

Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Thu, 16 Aug 2012 15:12:31 GMT
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The H290C was designed from the start to be a bolt-on upgrade, that would require a minimum of crossover changes. The acoustic centers are in the same place and the patterns are similar, so the pre-2012 crossover used with the old H290 horn can be used and the primary lobe is forward and centered. But the upgraded H290C waveguide benefits from an upgraded crossover that has different values in a couple locations. Its impedance curve is different, necessitating the removal

identify and locate these components.

provides three functions, 1. To provide full-band attenuation, 2. To provide mass-rolloff compensation in the top-octave and 3. To provide specific damping for the core-splitter, which sets the SPL level of the crossover region independently of the midband. This network provides maximum flexibility, allowing the low, medium and high frequency ranges of the tweeter's transfer function to be set independently.

This network is created by components R1/R2 and the compression driver itself. In many cases,

shunt is required. But in the case of the H290C, a shunt resistor Rs is used.

The input leg R2 sets the load on the core splitter, which sets the damping. High levels of damping (low resistor values) brings down the SPL in the crossover region. Low levels of damping (high resistor values) increase SPL in the crossover region. The attenuator R1 sets the midband SPL level, and interacts with the output leg, providing mass-rolloff compensation. Optional components C1 and Rs are used to further tailor the response.

As for audible differences, remember that I always found the old H290 horn to a pretty good part, and didn't change it even when several new waveguide products began to enter the market. I found it to be better than most of the so-called waveguides out there, for one reason or another.

The only thing I really didn't like about it was the edge at the mouth. I would have preferred it to have a rounded lip. But that's probably not audible, really. Constant directivity horns with sharp edges in the throat are audibly harsh and "spitty", and I think the edge at the waistbanding expansion in some CD horns also contributes to that somewhat. But it doesn't seem to be so much the case with horns having their only edge at the lip, like the old H290 had. I suspect distance from the throat matters most, and so an edge right at the mouth was least objectionable. Still, I prefer a gentle radius at the mouth, making the horn smooth everywhere.

Of course, the basic flare profile of the H290 is different too. The new H290C uses an OSEC flare profile, which is the shape that best transforms a plane wave into a spherical wave section without "fracturing" it. The wavefront expansion is at right angles to the wall at all points through the horn. Other shapes cause it to twist and bend as it progresses down the throat, making modes or "pockets" of distortion. The wavefront is slightly distorted as it travels down the throat of any other shape. So the oblate spheroidal profile is the perfect shape because it allows the wavefront to pass through the horn without distortion.

How audible is this? How much distortion of the wavefront is too much?

I don't know the answer to that question. At this point, I don't think anyone does. I know that the OSEC shape is mathematically correct, so it's at the "best" end of the scale. I also know that horns with diffraction slots in their throats are just the opposite, audibly harsh and spitty at the "worst" end of the scale. In between are the horns with other shapes.

In my experience, the biggest thing is to stay away from horns with sharp edges in them, particularly those close to the throat. If the horn is gently radiused from throat to mouth and holds the right patern without sharp edges, it's a 90% good horn, at least. The ultimate horn uses a pure OS/EC flare, and this is what the H290C is.

---

Subject: Re: H290C Horn/Waveguide
Posted by Maxjr on Thu, 16 Aug 2012 19:11:46 GMT
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Thank you so much for that thorough response. I look forward to trying out the new H290C horns.

---

Subject: Re: H290C Horn/Waveguide
Posted by gofar99 on Sat, 18 Aug 2012 19:35:20 GMT
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Hi All, I got the horns in and they are huge improvement over the H295s I had in there already (got them as the original 290s were out of stock and delayed back order). Well worth the effort to put them in.

---

Subject: Re: H290C Horn/Waveguide
Posted by Maxjr on Thu, 23 Aug 2012 03:48:01 GMT
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I just ordered my pair!  I can't wait to try them out

Subject: Re: H290C Horn/Waveguide
Posted by Quiet_Storm on Mon, 27 Aug 2012 04:28:06 GMT
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Wayne, I'm considering upgrading to the H290Cs on my 4 pis. This thread has me hooked!

By the way, I've been loving my 4 pis and 3 pi subwoofers. I don't think anyone's left my apartment unimpressed. However, now I have a bit of upgrade-itis plus I'm considering a build for my dad, so I might try to knock both out in one purchase.

Also not to threadjack too badly, but I'd like to get your thoughts on the best speakers for my dad. He has an entertainment center in a corner that is closely flanked by his speakers. Based on this limited arrangement (and no room for flanking subs), I'm thinking 2 pi towers might be the way to go. What do you think?

Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Mon, 27 Aug 2012 13:10:07 GMT
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Quiet_Storm wrote on Sun, 26 August 2012 23:28Wayne, I'm considering upgrading to the H290Cs on my 4 pis. This thread has me hooked!

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Subject: Re: H290C Horn/Waveguide
Posted by skywave-rider on Sat, 08 Sep 2012 18:48:47 GMT
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Wayne, looks like the H290C waveguides will be here Monday, though UPS says they are in NY right now!

Until I get my woofers for the eventual 3Pi, I intend to set up the H290Cs in my home rig.

The home rig uses the 4Pi crossover/DE250/JBL 123A-1.
I have added 20dB attenuation from your chart plus an LPad for more attenuation and adjust-ability. Currently running QSC waveguides.

---

Subject: Re: H290C Horn/Waveguide
Posted by skywave-rider on Tue, 11 Sep 2012 14:24:51 GMT
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FYI, got the H290Cs yesterday and immediately installed them in my home rig. This is a temp setup, as I eventually intend to do a 3Pi build.

But, even in my non optimized rig, I can tell you the H290C sounds superb. In comparison to the QSC HPR 152i, which I think is excellent and have been using for several years, I hear less "distortion." That may relate to modes in the WG, not sure. The feeling is that the H290C is cleaner.

[The "rig" is: JBL 123A-1/DE250/H290C/4Pi crossover with 20dB attenuation as per Wayne's chart and C1 removed. Running with horn on top, not in baffle, temporarily.]

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Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Thu, 13 Sep 2012 14:37:38 GMT
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Glad your new waveguides sound good to you.

Interestingly, your impressions are the same as mine. I've measured the H290C and I've listened to it, and my listening impression seems subjectively more of an improvement than the measurements show. The H290C waveguide just really sounds natural to me.

Other people have said the same thing too. There's been enough time now for people to install their new waveguides and listen to them. The feedback I'm getting is very positive. I'm hearing a lot of similar opinions, using phrases like "smoother", "less distorted", "more natural" and "cleaner sounding".

The measurements are good, but the old H290 measured surprisingly good too, better than most waveguides out there. So by response measurements, you might not expect much difference between the Eminence H290 and the new Pi H290C, maybe not even enough to hear. While the H290C's oblate spheroidal / elliptic cylinder flare profile is the best shape, in my opinion, other

profiles can be nearly as good provided they are close enough.  But the H290C is better sounding, probably because it stays true to the OS/EC flare profile.  Comparison of measurements don't really show this improvement as much as one might expect.

Of course, the measurements I'm talking about are just response and polar measurements, and they will only show very strong internal reflections in the form of response spikes. Smaller reflections won't show up in a response chart, and it may be that this is the difference. It would make sense, given the OSEC waveguide/horn generates the least (HOM) high-order modes. So I think the difference, while subtle, is audible.

I'm also pleased to hear your comparison of the Pi H290C with the QSC waveguide.  I've received emails from a few others that compared it with the JBL and SEOS waveguides as well.  I'm getting unanimous feedback that the H290C sounds better.  This, again, I attribute to the pure OSEC flare.  Other manufacturers deviate from it for one reason or another.

The new H290C waveguide just sounds better. I thought maybe it was just a proud papa thing, but since I'm getting feedback that the H290C sounds "smoother", "less distorted", "more natural" and "cleaner sounding" than the old Eminence H290 and other waveguides, I'm starting to think it isn't just me. Many people are reporting back positive results like this.

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Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Thu, 29 Nov 2012 16:54:44 GMT
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Here's a link to a thread that discusses physical dimensions of the H290C horn/waveguide: H290C dimensionsIt's handy for those that want to route a groove in their baffles for flush mounting.

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Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Wed, 30 Jan 2013 03:04:45 GMT
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Subject: Re: H290C Horn/Waveguide
Posted by crescendo on Wed, 20 Mar 2013 23:45:06 GMT
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Hi Wayne,

I'm new here (you may have seen me on diyaudio) and by way of searching many links of a chain, I found your H290C.

I haven't seen this question asked or answered yet, so I'll ask here. This is more a H290C question than a Pi Speakers system-question. I'm working on building a 2-way PA top with 12" woofer (probably the Beta 12A-II) and a 1" compression driver (Radian 475PB-16). Is there any reason(s) your H290C wouldn't work well for PA applications?

My next step is to discover how to implement alignment in the 2-way passive crossover system, as the CD horn will be directly in front of the woofer several inches. I have downloaded your crossover primer - might I find my answer there?

Best regards,
Justin

Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Thu, 21 Mar 2013 02:26:47 GMT
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The H290C is the best 90°x45° horn/waveguide available, truly a no-compromise design. So naturally, I would suggest it for any DI-matched two-way speaker or constant directivity cornerhorn.

The loudspeaker models I make using that waveguide are the ones I found to be the best out of a few dozen that once made up my line, so I find them to represent the best of the best. I wouldn't make any other design choices than those.

That said, there are plenty of other similar components that work very well. An example is the Eminence Kappa line of drivers, which are very similar to the ones I use in some of my models, and which have been used by many DIYers on this forum. There are lots of others too, lots of ways to "do it right" but of course lots of ways to do it wrong too.

So my suggestion is to study the links in the Pi Speakers FAQ, especially those in the "Crossovers" and "Simulations and Measurements" sections. Also look at the "General Information" section, especially the post called "Notes for the DIYer". It has links to some of the most useful notes for designing speakers like these. For example, "Crossover optimization for DI-matched two-way speakers" describes my exact crossover design process including a video showing how to measure the forward lobe by finding the vertical nulls that mark its edges.

Subject: Re: H290C Horn/Waveguide
Posted by Bill Epstein on Thu, 21 Mar 2013 13:46:19 GMT
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"But the upgraded H290C waveguide benefits from an upgraded crossover that has different values in a couple locations. Its impedance curve is different, necessitating the removal of

and locate these components."

I slept through, as I have been doing since high school , the technical details of the H290C and installed them without changes to the boards. Even before the crossover change I could hear an expanded soundstage in general and clearer exposition of the minor themes of a musical score. When I woke up and corresponded with Wayne I added the Rs resistor that softened the mids. Further discussion revealed that I also had to snip C1.

Once done, and liberally covered with rope caulk, the H290C are better-sounding than the Eminence: tonally more neutral with a clearer presentation of nuances like Violas under Cellos and brushes on Cymbals

Speaking of Violas:

What's the definition of a minor second?
Two violists playing in unison.

What's the definiton of "perfect pitch?"
Throwing a viola into a dumpster without hitting the rim.

Why do violists stand for long periods outside people's houses?
They can't find the key and they don't know when to come in.

Subject: Re: H290C Horn/Waveguide
Posted by rkeman on Thu, 21 Mar 2013 19:20:48 GMT
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May I ask the exact crossover changes required for both the 3Pi and 6Pi speakers? Also, it is difficult to judge the reflectivity of the H290C from the photgraphs on the website. Would you characterize it as flat, satin or glossy? Both of these factors would significantly effect the decision to replace the current Eminence waveguides or not.

Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Thu, 21 Mar 2013 20:28:22 GMT
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compresion driver.  Alternately, there is a position on the board for this resistor so you can install it there if you want instead of hanging it across the driver terminals.  The Rs position on the board is right beside C1.

Here are some additional comments by Bill Epstein, followed by waveguide design philosophy information:
An amazing listening session with the H290CThe finish of production waveguides is satin.  There are actually samples of many different ABS blends shown earlier in this thread, and that's why it's hard to tell what the finish is.  There was a glossy blend I tried early on, and another blend that was a little less glossy but still shinier than what we eventually settled on.  The final ABS blend I

loudspeaker with H290C waveguide:

As an aside, I chose the ABS mixture largely for its dimensional stability and consistency.  The mold shop gave me samples of waveguides using several different mixtures to evaluate, some that were really shiny, some that were more dull.  Some held dimensions well, others less so.  I placed a priority on dimensional stability, and the ABS blend that is most consistent tends to be less shiny, more of a satin finish.

ABS plastic is a mix of three substances, styrene, acrylonitrile and butadiene.  The proportions can vary from 15% to 35% acrylonitrile, 5% to 30% butadiene and 40% to 60% styrene.  By varying the mixture, you can achieve different properties.  Higher styrene tends to make a shinier finish, but we found a little bit less tends to make the device more dimensionally stable, more uniform through the hold and cooldown cycles of the molding process.  Since we prioritize dimensional consistency over finish, that sets the material to one with a surface that I would characterize as being satin black.

If you want a different finish, the waveguides can be painted.  Enamel adheres very well to these waveguides, so you can spray paint them to be glossy, flat or even a different color.

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Subject: Re: H290C Horn/Waveguide
Posted by zheka on Tue, 23 Apr 2013 14:59:08 GMT
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Hi Wayne,

I just recently noticed that H290C directivity sonograms are plotted over linear frequency scale. Do you have versions of the same plots but with logarithmic scale?

thank you

---

Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Tue, 23 Apr 2013 15:28:38 GMT
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zheka wrote on Tue, 23 April 2013 09:59I just recently noticed that H290C directivity sonograms are plotted over linear frequency scale. Do you have versions of the same plots but with logarithmic scale?

focused on the directivity midband up, because down in the crossover region, the midwoofer and tweeter patterns blend anyway.  In the crossover overlap band, tweeter directivity is shadowed by the midwoofer.

That's also why I didn't consider a secondary flare to combat waistbanding.  I wanted the flare to be purely OSEC, to make the wavefront propogation stay perpendicular to the walls as much as possible.

Subject: Re: H290C Horn/Waveguide
Posted by zheka on Tue, 23 Apr 2013 16:03:44 GMT
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some for you, as time permits. I was really more focused on the directivity midband up, because down in the crossover region, the midwoofer and tweeter patterns blend anyway. In the crossover overlap band, tweeter directivity is shadowed by the midwoofer.

That's also why I didn't consider a secondary flare to combat waistbanding. I wanted the flare to be purely OSEC, to make the wavefront propogation stay perpendicular to the walls as much as possible.

I am not sure I can tell from the sonograms where the waistbanding takes place. The normalized ones seem perfectly uniform all the way down to 1K.

is that because of the scale?

Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Tue, 23 Apr 2013 16:15:44 GMT
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Yes, it really is.  More so the algorithm that creates the stratified sonogram, I think.  It appears to try and fit each curve into 6dB slots.  In that case, I think the individual curves probably jump from 5dB to 7dB, so the 6dB bin isn't filled until the curves that reach 7dB, something like that.  Because you can see the waistbanding in the bottom octave in the 12dB strata, but not so much in the 6dB strata on that sonogram.  You can see it a little better on the unstratified charts and also on the chart that isn't normalized. But as I said, it's not something I am really concerned about, since the midwoofer and waveguide patterns blend in that region.

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Subject: Re: H290C Horn/Waveguide
Posted by zheka on Tue, 23 Apr 2013 16:20:15 GMT
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got it, thank you.

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Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Tue, 30 Apr 2013 18:15:00 GMT
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In the chart above, you can only really see evidence of waistbanding in the 12dB strata. As I said, I think this is largely caused by the renderer, which seems to fill the strata with any values less than the stratification level without any interpolation or curve fiting.  The waistbanding level is less than 6dB lower than midband, so it just doesn't show up.

Also, the scale is logarithmic which reduces the size of the waistbanding region, making it more difficult to see.

To help better illustrate waistbanding in the H290C, we can change the scale of the sonogram to logarithmic.  That stretches the area where waistbanding occurs.  See the charts below:

H290C horizontal sonogram using logarithmic scale

H290C vertical sonogram using logarithmic scale

These are sonograms made for the H290C using a different renderer and plotted on a logarithmic scale.  The measurements were made in a different environment too, so there are slight differences in the data but it shows general agreement with the other measurements.  The biggest difference is in the rendering and the logarithmic scale, where here we can sort of put the waistbanding region under a magnifying glass.

See the color scale at the right side of each chart.  This legend shows us a color gradient mapped

to SPL.

You will notice that horizontal waistbanding centers around 1.8kHz, and its effects are about 2dB reduction of sound at 45° compared to the midband levels. That's what waistbanding does. It reduces output slightly at the edge of the beam.

As a sanity check, we can calculate waveguide beamwidth using formulas from Keele's paper, "What's so Sacred About Exponential Horns?"

Pattern Control Lower Limit = (106 / Mouth Width * Wall Angle)
Waistbanding Frequency = 1.5 * Pattern Control Lower Limit
Waistbanding Pinch Angle = 2 * Pattern Control Lower Limit / 3

Therefore, the H290C has properties somewhere in this range:

106 / 11" * 85° = 1070Hz (lower limit of pattern control)
1070 * 1.5 = 1.6kHz (waistbanding center frequency)
2 * 85 / 3 = 60° (waistbanding minimum beamwidth angle)

Earlier measurements showed waistbanding centered around 1.4kHz. The measurements above show it to be centered around 1.8kHz. Both are reasonable, given the different environments they were taken in, and both match our expectations of 1.6kHz fairly well. One is a little higher than predicted, the other a little lower, but both are within 10% of what Keele's formula predicts. In each case, you can look at the charts and see less output at the waistbanding minimum frequency than midband. It falls a couple decibels more in the waistbanding region than it does at higher frequencies.

In my opinion, the 2dB loss at 45° from waistbanding is acceptable, especially since the woofer and tweeter are blended in the crossover region anyway. Even if they weren't, as is increasingly the case with the larger midwoofers, what we're really talking about here is a slight decrease in output at wide off-axis angles. By slight, I mean practically nothing. The 2dB drop at wide off-axis angles is completely inaudible.

Waistbanding is more damaging in a prosound implementation. In that application, the problem is not so much the slight squeeze of the pattern as it is the secondary lobe, which affects arrayability. But in this case, we're not concerned with that. A two-way or three-way speaker using an H290C waveguide has no other sources with radiation at angles that would create an interference pattern with the secondary lobe.

The thrust of the H290C design approach was to shift all anomalous behavior as low in frequency as possible. The idea was to sacrifice a little bit of waistbanding at the bottom end for smoothness from midband up. Crossover occurs between 1.2kHz and 1.8kHz, with that region blending woofer and tweeter output together. So by optimizing tweeter performance above that point, we are optimizing where tweeter fidelity is needed the most.

What we gain in the trade is a flare profile that keeps the wavefront propogation perfectly perpendicular to the wall angle all the way through the horn. We also gain better acoustic loading, which is important in a conical horn or waveguide, because they are characteristically weak in this

regard.  They need all the help they can get.  Improved acoustic loading provides smoother response, greater efficiency and lower distortion.

We haven't talked much about distortion, but consider that for a moment.  By increasing efficiency, you reduce drive requirements.  So not only does the improved acoustic load reduce diaphragm excursion, but it also increases efficiency, which reduces the drive requirements as well.  This, in turn, reduces excursion even further.

A 3dB increase in sensitivity means 1/2 power is required to obtain the same SPL.  So the distortion reduction is improved by two mechanisms, one being the reduced excursion from loading, the other being reduced excursion from reduced drive signal.  The improvements from horn loading are cumulative where distortion reduction is concerned.  This is true in all horns, basshorns and midhorns, but even more true in compression drivers, because they are designed for use where loading is good.  They do not have much excursion capability, because they're designed to be used on a horn, not on a baffle.

---

Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Wed, 12 Jun 2013 15:45:31 GMT
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More information in the thread below, including implementation considerations and comparisons with other designs:
Uniform Directivity - How important is it?

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Subject: Re: H290C Horn/Waveguide
Posted by Wayne Parham on Tue, 03 Dec 2013 22:32:04 GMT
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There were several influences that drove my decision to create this horn.  The most important one was an observation that radial horns having relatively constant horizontal directivity sounded best to me.  Objectively, they had smooth response and uniform horizontal directivity.  Their physical features were much like modern waveguides, having no sharp edges in the flare.

The H290C is very much like a radial horn of similar size, except that its OSEC flare profile is defined as the hyperbola created from a line drawn tangent to an elliptic cylinder or oblate spheroid:

When I first heard about this flare profile, I began to study it and found this shape was used in other disciplines as an antenna, horn, lense or other waveform radiator.  This is an important

"litmus test" for me, because the most successful ideas tend to be used in all engineering fields. Where I see things in just one field (and especially in audio), I am skeptical. Audio is saturated with fads and misguided pseudo-science, some even coming from big names in the industry. But this isn't one of them, and devices created using this profile provide fairly clear advantages.

However, the advantages are only found if (and this is a big "if") the waveguide/horn is properly built. Just having this basic shape isn't enough. Just like you can make a good exponential horn or a bad one, or even more so a good conical horn or a bad one, this flare profile has a few "sweet spots" and a bunch that aren't so hot. One is well advised to model the horn, optimizing it for best response and beamwidth/coverage. It isn't a "given" that this particular profile can be used no matter what exit angle is desired. Some work well, but some, not so much.

That was the basis for the last post, just above. It gives a feel for a well designed horn, and one that isn't optimized as well. Both have the same coverage pattern, but one has significantly more ripple.

More information:

The Sound Field and Radiation Impedance of a Hyperbolic Horn, by Vincent Salmon. This is the classic paper defining "Salmon family" horns.
The Webster Equation Revisited, by Sjoerd Rienstra. Another look at the famous 1P model, and it's limitations.
Reply to "How Horns Work", an overview on horns based on elliptical coordinate systems by Earl Geddes.
The horn-feed problem: sound waves in a tube joined to a cone, and related problems, by P. A. Martin. This paper looks at the interface between planar source and waveguide, and it invites a study of other disciplines, such as waveguide/horns used for electromagnetic radiation.
Geometrical representation of the fundamental mode of a Gaussian beam in oblate spheroidal coordinates, by Barbara Landesman. This paper looks at the fundamental propogation mode and higher-order modes when using devices based on oblate spheroidal coordinates.
A New Mathematical Model for a Propagating Gaussian Beam, another look at wave propogation through OS devices by Barbara Landesman
The Paraxial Approximation, an explanation of the concept.
Optimum Horn Mouth Size, by Don Keele. A paper written that speculates there is an optimum horn mouth size. It suggests that the radiation is neither planar nor spherical, but something in between.
Wave Propagation and Radiation in a Horn: Comparisons Between Models and Measurements, by Eveno, Dalmont, Caussé and Gilbert. Further study of the planar versus spherical radiaton models, a comparison showing differences.
Input impedance computation for wind instruments based upon the Webster-Lokshin model with curvilinear abscissa, by Thomas Hélie, Thomas Hézard and Rémi Mignot. This paper models horns and waveguides using an improved 1P approach that accounts for visco-thermal losses at the horn walls.
Computer Simulation of the Acoustic Impedance of Modern Orchestral Horns, by A. Benoit and J.P. Chick. A study of computer models used to calculate horn impedance. It proposes using a 3D element model rather than a 1P transmission line model for greater accuracy.
A Modeling and Measurement Study of Acoustic Horns, by John Post and Elmer Hixson. An exhaustive study of models and measurements, and of comparisons between them, seeking to

refine models. Both 1P and 3D approaches are explored. It discuses propogation modes in some detail, from primary to high-order modes. Appendix A discusses Electromagnetic and Acoustic analogies, which I think is always important. I personally look for things that span across multiple disciplines, because truly good approaches always do.
Horn Loaded Loudspeakers, by Richard Morgans at the Department of Mechanical Engineering, University of Adelaide. This is another very elaborate study of various approaches to using mathematical models to simulate horns, and comparing them with actual measurements.

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Subject: Re: H290C Horn/Waveguide - closest equiv. in 1.5" or 2"?
Posted by tubino on Thu, 17 Sep 2020 19:41:39 GMT
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It has been almost seven years since Wayne posted this amazing analysis and explication of waveguide optimization for room use, and a compelling case for the H290C. I bought my pair and I'm convinced.

For a different system though I want to use a larger compression driver, with 1.5" or 2" exit. Wayne, are you aware of a large format waveguide that is consistent with the design principles in the H290C? There are a lot of constant directivity 90x40 waveguides out there and I'm pretty lost.

---

Subject: Re: H290C Horn/Waveguide - closest equiv. in 1.5" or 2"?
Posted by Wayne Parham on Fri, 18 Sep 2020 04:09:24 GMT
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I put all of my focus on the H290C, and it's predecessor, the H390C. That was a wood horn/waveguide with the same profile but with much more mouth radius because it was designed to be free-standing and therefore have no baffle loading. But both are for 1" exit compression drivers.

I was able to do most of the acoustic development work back when I was making the H390C because it was cut on a CNC machine. So I was able to cut a physical model, test it and make incremental improvements.

Sometimes, lessons learned with one size driver don't transfer to another. But I find this more true of cone drivers than of compression drivers. So some of what I learned while optimizing the 1" drivers might transfer to larger drivers.

Here are a few main points:

1. The basic flare starts with an oblate spheroidal profile and then transitions to a flare based on elliptic cylindrical geometry. Said more simply, the throat is round and the mouth is rectangular. The same OS expansion equation is used to plot each axis, but the asymptotic angle is different in order to get the 90° x 40° shape.

A similar profile can be created with a OS to PS transition. That's oblate spheroidal to prolate spheroidal. It makes a very similar horn/waveguide but the mouth is oval-shaped instead of rectangular.

Each of these three coordinate systems are related: OS, PS and EC. They all make very similar flare profiles, just with different shaped mouths. Oblate spheroidal horn/waveguides are round, prolate spheroids are oval and elliptic cylinders are rectangular.

2. I find that acoustic loading is important. Waveguides are closely related to conical horns, which don't load well at low frequencies. But they still provide some acoustic loading and I think this is important to sound quality. So do not discount the quality of acoustic loading.

3. Radiusing the mouth edge, gradually opening up wider than the OS/EC profile, helps reduce waistbanding at the lower frequency range. With the right amount of radius area, you can completely eliminate waistbanding. But the radiused area does not contribute any acoustic loading. So it's almost like the horn/waveguide length ends at the point where the OS profile ends and the radiused profile begins.

4. Another thing that affects acoustic loading is the expansion rate. A horn/waveguide that has less expansion loads better. But this necessarily limits the overall coverage angle. I found empirically that a 90° x 40° waveguide is about as wide as can provide enough acoustic loading to offer smooth response. Any wider and the quarter-wave modes become pronounced, especially if a lot of the profile is sacrificed for waistband-reducing radius. For example, the H290C is actually a smidge under 90° in the horizontal, and it uses baffle loading rather than a lot of radiusing at the mouth.

5. If large size is not a problem, then you can have enough mouth radius to completely eliminate waistbanding and still have enough length to provide good acoustic loading. This makes a pretty large device though, and the extra mouth area prevents close vertical spacing between the waveguide and the adjacent driver in the system. This can make it hard to get the forward lobe tall enough - The vertical nulls might narrow too far. But with a low enough crossover point, the system can have wider vertical spacing between subsystems and still have a nice tall forward lobe with widely spaced vertical nulls.

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Subject: Re: H290C Horn/Waveguide - closest equiv. in 1.5" or 2"?
Posted by tubino on Fri, 18 Sep 2020 11:40:23 GMT
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Thanks, Wayne. That will take me a while to digest, but it confirms my suspicion that the common PA options are limited in several ways...

BTW, so you have any of the wood 390C available to sell?

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Subject: Re: H290C Horn/Waveguide

Posted by Wayne Parham on Fri, 18 Sep 2020 13:38:47 GMT
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tubino wrote on Fri, 18 September 2020 06:40BTW, so you have any of the wood 390C available to sell?

Sorry, no.  The H390C was very expensive and we stopped stocking them after we had the H290C mold made.