Subject: Speaker placement and wavefront launch
Posted by Wayne Parham on Sun, 02 Oct 2011 05:35:04 GMT
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The ideal: The constant directivity cornerhorn. In this configuration, the sound source is within

confining radiation to the angle of the walls. There is no waveform disturbance - It creates a perfect section of a purely spherical wavefront from the corner into the room.

Of course, not all rooms are suitable for constant directivity cornerhorns. Some have obstructions or entryways near the corners. Others have corners that are just too far apart. So not all rooms can support constant directivity cornerhorns.

This is a look at what other placements do to wavefront propogation. Let's start by moving the sound source slowly out from the apex of the corner, to see what happens. Where we cannot be

placements near boundaries? Or should speakers be placed far away, if they cannot be

I suppose it might be helpful to define acoustic scale. Things that are said to be acoustically close

sum as a single sound source. A boundary that is acoustically close is not a reflector, but rather a confining boundary, which is equivalent to a waveguide, with the bounding surface setting the radiating angle.

Things are acoustically distant if they are several wavelengths apart. They will not sum, but will not cancel either. They will develop interference patterns of energies and nulls, much like a

where interference is worst at close range, but where spherical radiation emerges within a short distance. All sound sources will develop spherical radiation at large distances, and the acoustic scale sets the range.

is so often found in home hifi installations. In this range, wavefront propogation, while not being as pure as acoustically close sources, does become spherical before the wavefront reaches the far walls. This is a generality, of course, but I think it's a reasonably useful one, and makes a good working definition of acoustic scale, e.g. close, distant and transition.

Note that the wavelength of 500Hz is 27". At 1kHz, it's half that, 13.5". These are important figures because this is the region where most matched-directivity (waveguide) speakers become directional. It's useful to be able to position speakers in the room where boundaries influence this range and below. So one should think in terms of one to two feet, when considering wavelengths in these illustrations.

apex of the corner. There is a mild band of reduced amplitude right down the center, and there is definite wavefront distortion but it isn't too bad except very close to the speaker.

wavefront distortion, worse as the speaker gets further away from the walls. But move just a little ways from the speaker, and the wavefront becomes spherical. There are also two bands of reduced amplitude, one on each side.

Now let's move it to a full wavelength away. And let's look at the expansion as it develops, to get a better view of the way energy is distributed. Note that black areas are pressure minima, and color is pressure maxima.

One cycle:

Second cycle:

Third cycle:

Now, let's see the wavefront expansion through the room. It is clearly distorted up close to the speaker, and it remains that way for some distance. But the wavefront is still what I would call "pseudo-spherical" (for lack of a better word), in that it retains that basic expansion, on average.

Now let's see a typical loudspeaker placement, closer in from the side wall than from the wall

wall. When the speaker is placed this far from the walls, the wavefront becomes pretty fragmented. In terms of actual distance, for a 500Hz tone, this condition would exist with the speakers four feet from the back wall and six feet from the side wall.

All of these have been transition region distances, with the exception of the last one which was just past. That's the toughest placement to deal with, because the interference is worst. Ironically, it's also the one that is most popular, probably because it is "furniture friendly".

Now let's try moving the speakers much further, to minimize the influence of the reflections. Having the walls further away not only reduces the amplitude of the reflections, it also tends to make them less problematic at the center of the room, where listeners most likely will sit. As an

of actual distance, for a 500Hz tone, this condition would exist with the speakers eight feet from the back wall and twelve feet from the side wall.

You can see why some audiophiles often prefer to have their speakers placed far away from walls. It does tend to make the center of the room less jumbled, the wavefront is relatively clean at some distance.

I think this series of illustrations makes another point abundantly clear, that there's another useful placement choice, to make the speakers nearer to the boundaries. They can be very distant, or they can be very close. It's the range in between that should be avoided.

midrange. Above that, directional tweeters and absorbent materials can be employed to reduce reflections. Where possible, avoid speaker-to-wall distances between two feet and eight feet.

The best approach is clearly to use constant directivity cornerhorns. But where that's not possible, if even the speakers can be kept within a wavelength or so, this is helpful, and makes relatively clean wavefront propogation in the listening area. But if the speakers cannot be placed this close to a boundary, it is better that they be placed far from it.

Also remember that reflections at higher frequencies are easily absorbed. Tweeter frequencies can be absorbed nicely with thin material, such as curtains. As frequency drops, the absorbent material must be thicker, or at least spaced further from the boundary. Below 1kHz or so, even fairly thick rugs won't do it, you need a foam or something that's a few inches thick. Below 500Hz, it is really tough to find things that will absorb reflections. That's where sound source locations become really important, because you can't do much to absorb the sound.

More information:
High-Fidelity Uniform-Directivity Loudspeakers

Room modes, multisubs and flanking subs
Helper Woofer Location
Flanking Subs vs Helper Woofers

Subject: Re: Speaker placement and wavefront launch
Posted by Shane on Mon, 03 Oct 2011 03:40:15 GMT
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Great visuals Wayne!

I know my Heresy's sound best shoved into a corner as far as they will go. They weren't designed for it, but that's where they sound best. On the other hand, put any of my non-horn speakers (re. dome tweeters, etc...) and they get incredibly muddy.

Subject: Re: Speaker placement and wavefront launch
Posted by BeOfService on Wed, 05 Oct 2011 16:44:23 GMT
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Wow! Nice contribution Wayne. I feel educated, and will be trying some placement experiments when I get home.
Gary

Subject: Re: Speaker placement and wavefront launch
Posted by gofar99 on Wed, 05 Oct 2011 21:23:29 GMT
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Hi Wayne, Unless I missed something (always a possibility with us old dinosaurs), this is dependent on a single frequency being radiated. With sound made up of lots of frequencies it would seem that what works at one frequency would mess up another. I have run into this reinforcement, cancellation and what I'll call scrambling issue with the electrostatics I have. There are specific guidelines on placement and aiming directions, but it is still largely a trial and error process to get them just right.

Subject: Re: Speaker placement and wavefront launch
Posted by Wayne Parham on Wed, 05 Oct 2011 22:35:00 GMT
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The illustrations show radiation from a monopole source with boundary distances relative to wavelength. You're right that different frequencies create different patterns in the room, because the speaker is a fixed distance from the boundaries. But these illustrations show what the

whatever frequency/distance that is.

reflection, making it more of a bounding surface than a reflector. It is simply a waveguide at that point. At greater distances (with respect to wavelength), interference patterns develop, as are shown in the other illustrations.

At low frequencies, wavelengths are large so acoustic scale is large too. What I mean by that is two sound sources (or a source and a reflector) can be separated by further distance at low

room modes, a separate but very similar issue.

In the midrange, wavelengths grow shorter, yet not so small that reflections are easily trapped with absorbent materials. So the lower midrange is actually a tough range to deal with. It is nearly impossible to position a speaker in a small room where midrange quality isn't adversely affected by boundary reflections. In fact, the only configuration I know of that truly solves this problem in a small room is the constant directivity cornerhorn.

There are actually a few regions where indoors sound radiation patterns act differently. The lowest frequencies make up the pressure region, where wavelengths are long compared to room dimensions. Reflected sound sums constructively with the direct sound, so the whole room is pressurized equally. It can be thought of as slightly increasing air pressure in the room on one half cycle and slightly decreasing pressure on the other half cycle.

source, so reflected sound no longer sums constructively. This is where room modes are, typically in the 20-200Hz region. Pockets of energy form, with some places in the room having strong bass energy, and others having nulls. These pockets are in different positions depending on frequency and loudspeaker placement with respect to walls. They're fixed-position standing wave modes that setup between boundaries, mostly between opposite walls and floor/ceiling, but to a lesser degree diagonally from corner to corner.

As frequency rises, above about 200Hz, the distance (both in frequency and position) between the modes grows closer and closer together, so at some point they are so close you cannot distinguish them apart. This is called dense interference, and it is the characteristic of the reverberent field, in the statistical region.

A few other things can be observed about these regions. At higher frequency, the sound is sort of an averaged energy field. Reflections are usually many wavelengths from the direct sound, so they don't really sum with the original - they modify the direct sound signal several cycles later. It's a different phenomenon. Also, higher frequencies are more directional and much easier to absorb with damping material. In fact, many things that are in every home naturally absorb sound, like carpets and drapes. Tweeters can be designed that put the sound in a pattern with constant narrow beamwidth. So higher frequencies are usually much easier to deal with than lower frequencies.

Low frequencies are harder because the long wavelengths don't lend themselves to damping with fibrous materials. The only things that are really effective at damping low frequencies are large vibrating membranes. Actually, homes with framed drywall construction act as natural sound dampers at some frequencies, because the drywall vibrates and some of the energy is therefore lost. But they don't work at all frequencies. The panel absorber has to be sized to match the frequency band of interest.

But one can use a technique that provides dense interference at low frequencies, in order to smooth the sound field in the modal region. This is what multisubs and flanking subs do. The frequencies to focus on are from 20-200Hz, because this is the modal region. A close second is the range from 200Hz to 1000Hz, where most sound sources are not directional enough to be aimed.

My take away from all this is that it is best to use directional (monopole) speakers and to place them either right up against the wall or a long way away, like over eight feet. The best approach, in my opinion, is the constant directivity cornerhorn because it is close enough to the apex of the

acoustically close to the boundaries, so they have a perfect wavefront. Only the tweeter is operating high enough to be acoustically distant, and as I said earlier, high frequencies are easily absorbed with pleated drapes or whatever. The tweeter is directional too, so that helps.

The next best thing is to have sound sources either eight feet or more from all walls, or less than about two feet from the nearest walls. This is sometimes hard to do, because the acoustic center of the sound source is often in front of the speaker, and rarely at the back. So to have the face of the speaker be (just) two feet from the rear wall means it pretty much has to be scooted back nearly against the wall. But I'd rather do that than to move it out four or five feet. Having the

inches away - but it is better than being four or five feet out. If you can't put it at least eight feet away, it's probably best to move it right up against the wall.

That's really the point of this thread, the most important thing I wanted to point out. In having many discussions with people over the years, I find that one of the biggest misconceptions (audiophile) people have is that pulling speakers out away from walls is good practice. That is true only if the speakers are really far away from the walls, like eight to ten feet or more. If your room is 20 x 30, that's just not practical, and in this case, I see some people pulling their speakers out from the walls around four or five feet - which is probably the worst distance they could choose. That's why I wrote this, to suggest that it would be better to put their speakers right up against the wall than it is to have them four or five feet from it.

There is another solution, which I mentioned earlier. The flanking sub approach is one I

from the nearest boundaries, so self-interference notches form as a result. Speakers on stands get this self-interference notch from the floor, and often times they are also two or three feet from the back wall, making another self-interference notch, often in the same octave, forming a big wide valley.

A solution is to overlap two sound sources spaced a couple feet apart. The two sources can be a woofer and large midrange overlapping up to ~200Hz. This is the approach taken in my cornerhorns, for example. Another way to do it is with a 2.5-way speaker, with the lower helper woofer low-passed in the ~200Hz range. Or it can be a woofer in a separate box, placed a couple feet behind and to the side of a main speaker, sub on the floor and main speaker on a stand. This is a way to separate the sound sources in all three dimensions, smoothing what would have been notches from the floor and wall behind the speakers.

Subject: Re: Speaker placement and wavefront launch
Posted by gofar99 on Wed, 05 Oct 2011 23:14:37 GMT
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Hi Wayne, good stuff. I had started a long discourse on how dipoles made a mess of this and decided to can it. Those of us with ESLs and open baffle speakers have to re-think everything as a lot of the parameters interfere with each other. It took several months of careful listening and measuring to get mine right. I'm thinking of using concrete or epoxy to keep them from being moved (not really). I suggest that anyone considering any type of dipoles contact one of us with them first for some hints, suggestions and warnings on possible problems.

Subject: Re: Speaker placement and wavefront launch
Posted by Wayne Parham on Wed, 05 Oct 2011 23:20:24 GMT
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Well, that's right, Bruce. Dipoles are a different animal, and have a very different radiating pattern. I really don't think you can operate a dipole speaker close to a boundary with good results. They really need to be used in large rooms, set far away from walls so the anti-phase wave projected behind them doesn't reflect back and interfere with the forward wave.

Subject: Re: Speaker placement and wavefront launch
Posted by tom-m on Thu, 06 Oct 2011 04:30:45 GMT
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Hi Wayne,
At what point is a room too big for your 7pi corner horns? My room is about 18x20. I had mostly decided on building the 4pi, but this thread is making wonder if the 7pi would be a better choice for my room?

Thanks.

Subject: Re: Speaker placement and wavefront launch
Posted by Wayne Parham on Thu, 06 Oct 2011 05:29:29 GMT
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from the illustrations. You really notice the difference in the midrange. That's not to say the four

loses little, when properly setup. But the benefits of a constant directivity cornerhorn are obvious, and the difference is noticeable. Well worth doing if you have the right room.

So what's the right room, you ask. It's not really just about size, although larger rooms almost always tend to sound better than the smaller rooms, all other things being equal. But with a constant directivity cornerhorn, you need unobstructed wall space from each corner for about six feet on each side. You also need to be able to sit behind where the forward axes cross, which means you must be able to sit back at least half the distance the wall is wide. If you have a 20 foot wall between the speakers, you have to sit at least 10 feet back, which generally means you need a pretty deep room. You don't want to sit right on the back wall either, you want to sit several feet away from the wall behind you.

More information at the link below:
High-Fidelity Uniform-Directivity Loudspeakers

Subject: Re: Speaker placement and wavefront launch
Posted by skywave-rider on Thu, 06 Oct 2011 16:35:10 GMT
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Wayne,
In some of the examples you posted above a distorted wavefront close to the speaker eventually attains a spherical shape at a distance. How can the wavefront become "aligned" like that? I always thought the wavefront very close to the speaker would remain the same propagated out into space if there are no reflections.

Tons of great info in this thread. Thanks.

Subject: Re: Speaker placement and wavefront launch
Posted by Wayne Parham on Thu, 06 Oct 2011 19:46:46 GMT
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skywave-rider wrote on Thu, 06 October 2011 11:35In some of the examples you posted above a distorted wavefront close to the speaker eventually attains a spherical shape at a distance. How can the wavefront become "aligned" like that? I always thought the wavefront very close to the speaker would remain the same propagated out into space if there are no reflections.
I have two answers for you, one that you asked for and the other, you didn't.

First is the reason sound waves become spherical at a distance. All sound waves in free space tend to radiate this way, even if they start off as a plane wave (like from a vibrating piston) or are fragmented by reflections, diffractions or whatever. At some distance - again, in free space - they'll tend to form a spherical radiation pattern. The reason for this is superposition, a sort of averaging mechanism that forces them into this wavefront, the natural propagation mode of sound in free space.

Now the second answer, also related to superposition of waves. The same property that causes the wavefront to "settle down" into a spherical pattern at a distance is also what causes it to become distorted by self-interference, room modes, diffraction and refraction. When a wavefront encounters a disturbance like a sharp edge that causes diffraction or an object that refracts part of the wave, then a new vectored wavefront forms with a different trajectory, sort of a new virtual source. When a boundary reflects a wave, then it also can be seen as a virtual source. And of course, other (physical) sound sources create wavefronts of their own too.

All these kinds of things combine by superposition to create a wavefront that is anything but spherical. That's what makes the jagged looking wavefront, and it's what creates room modes and self interference notches. It's the mechanism that creates vertical nulls too. So the same thing that makes a wavefront spherical at a distance is also what makes it fragmented in the presence of interference.

Inside a room, the truth is the wavefront doesn't keep the spherical expansion even from the most perfect sources. The best case has a direct wavefront expansion that is spherical until it reaches the opposite walls (or furniture, people, cats and dogs). Boundary reflections create wavefronts that interact with one another to form a complex modal "checkerboard pattern" inside the room. The checkerboard pattern is "pockets" of peaks and nulls, positions where the sound is loud at a given frequency right next to adjacent positions where sound pressure level is low.

The shape of the modal pockets and their size and position are determined by frequency and positions of sound sources, reflectors, refractors and diffractors. At high frequencies, the pockets of energy are so closely spaced that they average together. Several of them span the distance between your ears, so they sound like a uniform sound field. At lower frequencies, the pockets are larger, wide enough you can move a few inches and pass between a high energy and low energy position. These larger modes become more noticeable. That's why we look to multisubs and flanking subs to help smooth this frequency region.

The thing that's nice about constant directivity cornerhorns is two of the most audible and troublesome self-interference problems are eliminated at the source. The reflection from the wall behind most speakers almost always makes a deep notch in the midrange, but there is no reflection from that wall when constant directivity cornerhorns are used. There is no horizontal self-interference, whatsoever, because the source is acoustically close to the walls all the way up through the midrange. And the midhorn and woofer overlap in the 100-300Hz range, which tends to smooth vertical modes. Where self-interference between the floor or ceiling reflection and one source causes cancellation, the other source being in a different location, fills it in. So the response is very good from about 100Hz upwards. No need for flanking subs with this configuration, although more distant multisubs can be employed to smooth lower frequency room modes.

installations cannot be done with them quite as close to the wall as I'd like, because they're physically large speakers. I usually put them on stands about 12" to 15" up, and toe-in 45° like the cornerhorns. This prevents me from putting them as close to the wall as I'd like, but the midwoofer isn't much further than two feet from the wall behind them. I put flanking subs on the floor, one beside each main, and push them back against the wall so they are offset in all three dimensions - several inches below, several inches behind and several inches beside. Each sub is run with the same signal channel as the main it is flanking, low-passed fairly high with a gentle second-order slope. I usually low-pass around 100Hz, and with a second-order slope, there is a fairly good amount of overlap up through the next octave, smoothing the lower midrange band.

Subject: Re: Speaker placement and wavefront launch
Posted by skywave-rider on Sat, 08 Oct 2011 20:30:12 GMT
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You've given me a lot to think about. Thank you.
I just did the water experiment, where I instigated 2 waves in a pool of water; where they converged I noticed an "adjustment" of the wavefront. Superposition I guess.

I'll have more questions.

Subject: Re: Speaker placement and wavefront launch
Posted by Wayne Parham on Sun, 09 Oct 2011 04:13:44 GMT
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It's neat stuff. The thing is, when you have constant directivity cornerhorns setup, you really get to hear what constant directivity sounds like. The sound field is uniform through the entire audio band, and the wavefront is unperturbed. Nothing else does it. Not dipoles, not planars or electrostats, not two-way waveguides, nothing.

I've seen a lot of my colleagues claim that constant directivity is most important above 1kHz. It's not true, it's just convenient. In fact, I think it's arguably more important to have controlled directivity in the low midrange, because that's where the nasty vertical modes, floor bounce and back wall bounce do the most damage. Those are probably the most important regions of the spectrum, and yet they are overlooked by many.

Then again, the flanking sub or helper woofer approach does work very well at smoothing that range. It's not like it can't be dealt with using more traditional speakers. But still, if you have a chance to use constant directivity cornerhorns, you'll see what I mean. There just really isn't anything like them.

Subject: Re: Speaker placement and wavefront launch
Posted by Wayne-o on Mon, 10 Oct 2011 14:33:31 GMT
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I agree on the importance of the low midrange. Thanks for the informative wave images.

Subject: Re: Speaker placement and wavefront launch
Posted by Shane on Mon, 10 Oct 2011 15:00:32 GMT
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Wayne, I think you should send me some 7Pi cornerhorns to "validate" your theory

---

Subject: Re: Speaker placement and wavefront launch
Posted by gofar99 on Wed, 12 Oct 2011 02:31:04 GMT
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Hi Wayne, Right after you send some to Shane, would you send me a pair to ,........

BTW, I working on a write up on how dipoles work in rooms from a practical aspect. When I fiddled with the math on them it will drive you crazy as it indicates that they can't work at all most of the time, between direct and reflected sound particularly in the lower mids there is no hope. Fortunately, in real rooms they don't seem to exhibit the problems to that degree. Tall ESLs like I have tend to have an advantage over some conventional designs as they act a lot like a line source. There are smaller reflections off the ceiling and floor. With the curved radiating surface it most likely has an effect on how they react in rooms vs the math. Wayne might have the answer there. I suspect that they act more on average power at a closer distance than conventional ones as opposed to the near field aspects that were in earlier posts.

Subject: Re: Speaker placement and wavefront launch
Posted by Wayne Parham on Wed, 12 Oct 2011 05:19:37 GMT
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Most of the dipole and planar folks I know tout the side-cancelling nature as helping reduce side wall reflections. This is true, since they have what is effectively about 120° radiation, and there is very little radiating straight out to the sides.

The problem is this doesn't actually help much on the side walls because there is still plenty of energy at wide horizontal angles. And of course, you have the whole rear wave to deal with. That's why I think they sound best when pulled far away from walls.

One place I find planars to sound really great is when they're up close, set just ahead of me, and angled in towards me. They have great imaging that way. But that arrangement sort of kills the room, making it unsuitable for anything else. Push the speakers back into a position where there is still usable living space in the room and the sound is terrible. They're like a beautiful girl that's way too tempermental to actually live with.

One of these days, you'll have to check out some constant directivity cornerhorns. If you have the right corners, they are all pluses, no downsides. They just plain do everything right.

Subject: Re: Speaker placement and wavefront launch

Posted by tom-m on Wed, 12 Oct 2011 15:46:53 GMT
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Hi Wayne,
Do the 7pi have the mid bass and low midrange punch that the 4pi have? I see that the 7pi is a little more efficient. But you don't have the 15 JBL playing the midrange with the 7pi like you do with the 4pi.

This is a great thread.
thanks.

Subject: Re: Speaker placement and wavefront launch
Posted by Wayne Parham on Wed, 12 Oct 2011 17:48:30 GMT
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Absolutely, the woofer in a constant directivity cornerhorn runs up to around ~300Hz, with a gradual first-order rolloff. It overlaps with the midhorn from 100Hz to 300Hz, smoothing the vertical modes. It gives a full, rich body to the fundamentals in that region, most noticeable in vocals, and instruments like piano, guitar and cello.

Note that middle C is 260Hz, which marks the approximate point where the woofer is starting to rolloff. The octave below that is covered by both midhorn and woofer. Below that, it's pretty much just the woofer. You don't need flanking subs with a constant directivity cornerhorn, because it is sort of built-in. There isn't any rear or side wall reflection, and the vertical modes are smoothed by the overlap between midhorn and woofer. The lowest frequency modes can be smoothed with distant multisubs, but flanking subs just aren't required with this configuration.

Subject: Re: Speaker placement and wavefront launch
Posted by Kingfish on Wed, 28 Nov 2012 17:54:44 GMT
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Now this is what I call a great source of information. Great visuals with just as good text to back it. Excellently detailed all the way around. Great job.
