



ZEN OPEN BAFFLE SPEAKER PROJECT

by Steve Deckert

April 2007

INTRODUCTION

There has been a peaked interest in Open Baffle Speaker designs on our Forums. Threads on the subject have remained active for well over year. Threads typically loose steam after only a few weeks or months so needless to say there is real interest in it.

The first question in the minds of those of us who haven't owned or at least heard a pair is "Do they sound good, and if so - how?"

Placing a speaker in a flat board rather than into a cabinet... On the one hand you have a di-polar speaker that puts out as much sound behind it as it does in front - usually good for imaging and sound stage depth. And of course no box to color the sound. On the other hand you have no box to prevent low frequency cancellation so no bass.

It goes without saying that most open baffle designs have more than one speaker, the second one is often placed in a box to generate some tone and bass. Others are just simply large in size with one or more 15 inch woofers helping out a smaller driver. The larger cone area of a 15 inch woofer with the added boundary effect from the floor can create enough tone and bass extension to prevent the main speaker from sounding thin. In all cases it is a design challenge to get any real bass out of a speaker stuffed in a board. Unless the board is extra large the distance a sound wave would have to travel to get from the front of the cone and intercept the out of phase wave coming off the rear of the cone is too short to prevent cancellation much below 100 Hz. If you go with a small baffle so it won't take up your whole room and like your speakers to sound like they disappear then you can expect the figure to be even higher.

MY INTEREST IN OPEN BAFFLES

Like anything out of the ordinary, I find Open Baffle speakers intriguing. I've heard many over the years, most I thought sounded better than I expected and a few sounded worse.

I see it as a battle between bass and imaging - to over simplify it. I also notice in many designs the lack of texture or richness in the lower midrange that a well done cabinet either adds or preserves.

I like to see things stay no more complicated than needed to achieve a goal when it comes to audio gear and speakers. Most Open Baffle guys are running at least two if not three or more speakers in their set ups. The main driver, a supplemental driver for more bass or tone, and a sub woofer.

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I see the fastest growing niche in the audio world as single driver full range crossover-less loudspeakers that can be driven with only a few watts. I would like to combine the huge interest in Open Baffle speakers with this niche.

A single driver with no crossover means a single glorious point-source. My interest in Open Baffle design would be to preserve this purity. If you add a second larger driver in the baffle you have all kinds of complications to address. The phase angle at any given frequency will be different between the two drivers, that's problem number one. Both drivers can't occupy the same point in space, that's problem number two. Problem number three is how to drive two drivers rather than one. You either have to wire them together or use another amp, cables, crossover? Either option opens a Pandora's box of possible ways the coherency of a single point source could be damaged.

A DESIGN GOAL (or FANTASY)

I would like an Open Baffle design that used a single 8 inch full range driver, and was small and sexy like a floor standing cabinet might be. I don't want a lot of cabinet or wide board to get in the way of imaging and the speakers ability to disappear. And I want it to have real tone and texture, like a well done cabinet. My guess is audiophiles who have ever built or designed an Open Baffle would ideally like the same things. It's almost like wishing for something out of nothing. This is no doubt why you don't see such an animal. Nevertheless it would like to get as close to achieving this goal as possible. Not only would I like it for myself, but I'd like to see the design (if successful) bridge the gap between the Open Baffle and Single Driver enthusiasts.



PREVIOUS ATTEMPTS

Over the years I've built a few Open Baffles. They ranged from sticking speakers in boards, to sticking speakers in slightly fancier boards. It was known going in that a sub would be used to help out the bottom. As a picky audiophile I observed that you can't help something out unless it is there to begin with. Even crossed over rather high around 120+ Hz there was a disjointedness to the sound. The subs always had a character all their own (usually pretty bad and each one different) that simply did not match the driver in the baffle. The problem was compounded when using tube gear to drive the baffle and solid state to drive the subwoofer. Anything that the main driver did well was poisoned by the non-matching driver, in this case, subs.

HARMONICS

Don't get me wrong, the OB's I tried didn't sound hateful, but I've gotten more and more sensitive to harmonics as time passes and I'll have to explain where I'm coming from before you understand what I'm getting at. As someone who has run a small studio for the past 10 years that hosts an open stage on Thursday nights I stay very calibrated to what live instruments sound like. I'm also a drummer who's really picky about how the kit sounds and how it's tuned. I've recorded every single session and often use those masters to evaluate speakers or amplifiers.

If you look at music, the thing that defines what you are listening to in all its subtle details is harmonics. The timbre of a given instrument would be impossible without the ultra complex harmonics that stem from fundamentals of each note. This is true anywhere in the audio band, and yes even if not especially in the bass. My kick drum is responsible for the heart beat in the music and most would perceive it as a bass note. However, while the fundamental tuning on the drum is typically around 40 Hz, every recorded beat from that drum contains harmonics and overtones clear up to 20 KHz. These harmonics are what make it sound real. They are how you can hear what type of beater head is being used on the pedals, and how you can hear differences in drum heads even if they're always tuned the same. It is why there are drum shells offered in Maple, Birch and a dozen other hardwoods - each gives the drum a different sound.

So my point with all this, is that if you want an instrument to sound real when you play a good recording of it on your stereo, these harmonics should be viewed as being like DNA and preserved in any way possible.

When you take the recording of the kick drum and reproduce part of it through one speaker and part of it through another speaker or system it will not sound like the real drum, only a recording of one. You've basically taken the DNA of that instruments sound and split it apart and tried to patch it back together.

This is not unlike Jurassic Park where they didn't have all the pieces for the dinosaurs DNA so they used segments from a frog's DNA to make it work.

To preserve the DNA a single driver with no crossover must reproduce the entire range of frequencies including the low frequencies.

RECENT ATTEMPTS

You know it's hard enough to engineer something that actually works well, but as an artist I'm also cursed with making it considerably more difficult by insisting that it be pretty - or esthetically pleasing. In my world the artistic side challenges the engineering and drives the whole process. Engineering things has nothing to do with brilliance, it's just plain tedious work. Hard to get passionate about number crunching by itself but easy when the artistic background theme is involved.

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Well, getting back on track, I saw a truly attractive Open Baffle speaker recently. It had an 8 inch full range driver in it, but also had an attached cabinet with a 15 inch woofer inside. Staring at it I began to wonder if it would be possible to make a similar looking speaker without the supplemental 15 inch woofer inside (imagine that)! I pictured an empty cavity that resonated in concert with the 8 inch full range driver. The resonance of the cavity would achieve the tone and texture. But would it work?

Having done something remotely similar with the design of the [Imperial SO](#) horn cabinet I knew that it was possible to achieve massive amounts of bass in a horn flare without actually having a driver directly coupled to it. Instead the driver fires out into the room past a carefully positioned slot where the slot becomes the throat of the horn flare. As far as I know this was and still is an original concept in horn design. It has so many advantages you'd have to read the papers on it to fully appreciate why I wanted to apply it in some way to this Open Baffle research.

Actually, integrating a horn mouth into this design really isn't an option. While possible, it would be too small in size to achieve any low bass. I am shooting for a goal of around 40Hz. A tiny horn flare that fits this profile would limit response below 100Hz. kind of defeating the purpose.



HELMHOLTZ

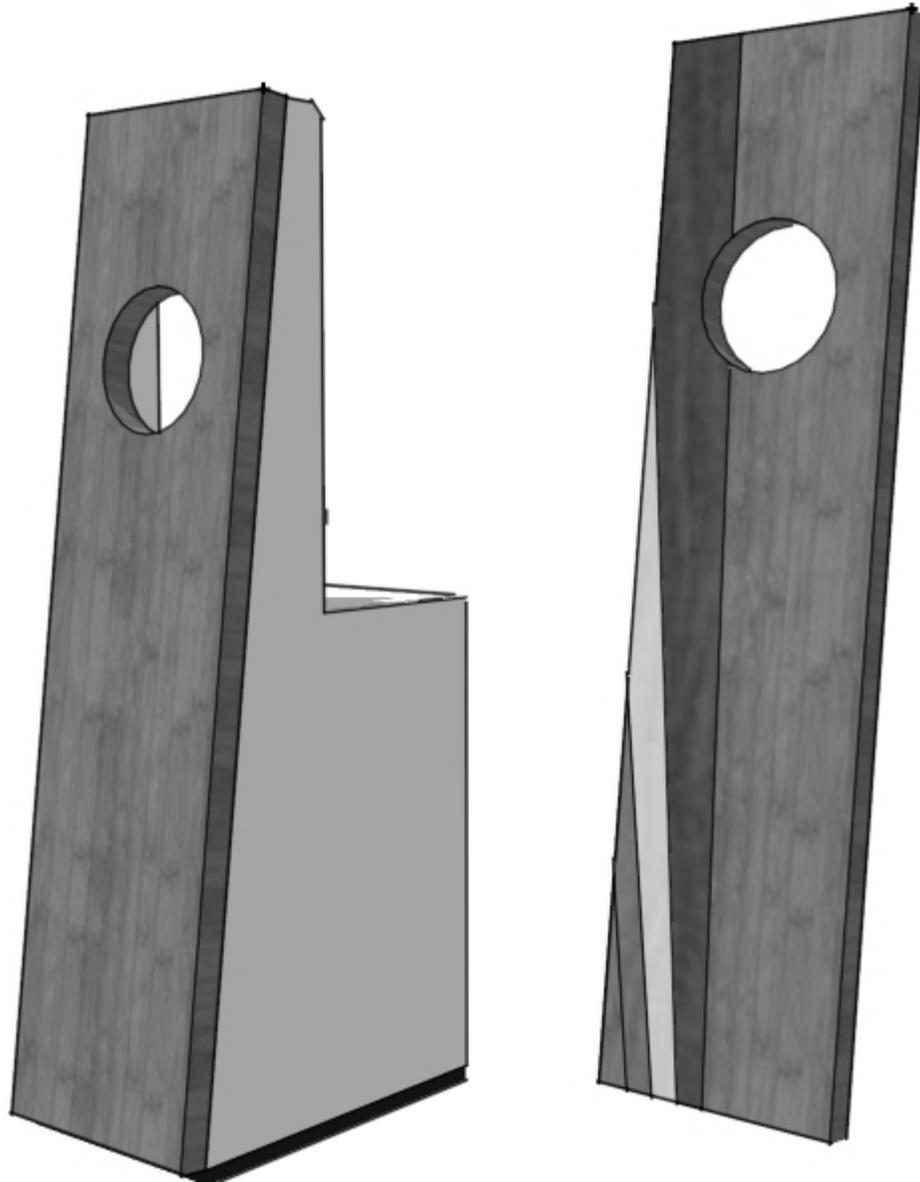
In this design the cavity must easily resonate when excited by a nearby speaker. I did a conceptual model on the computer to determine what it would take to make this cavity resonate across two octaves.

Specifically I was interested in how to couple the cavity to a tuned slot just below the back side of the speaker. This would involve creating a neck at the top of the cavity (like a coke bottle with respect to Helmholtz) and I needed to work through potential shapes. The formulas I found most helpful in determining the transmission loss characteristics of the neck, which would couple the cavity and driver were in a paper by Ahrnet Selamet and Iijae Lee from the Dept. of Mechanical Engineering and The Center for Automotive Research at Ohio State University The 2002 paper can be accessed at the Acoustical Society of America website and is recommended reading for anyone designing Helmholtz resonators for noise control or bass traps.

In fact, one could say that if this worked, it was a bass trap added to an open baffle that created the bass. Hey, now we're getting into the Zen zone...

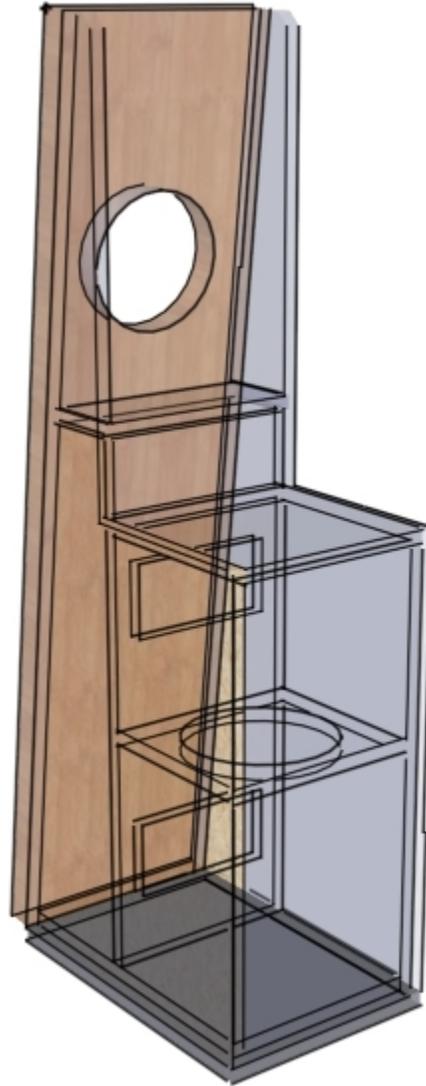
Armed with some idea of how to design the neck, I did a conceptual sketch of it and then built a rough prototype from that sketch out of drywall to find out if this was even going to work.

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Showing the front baffle is removable

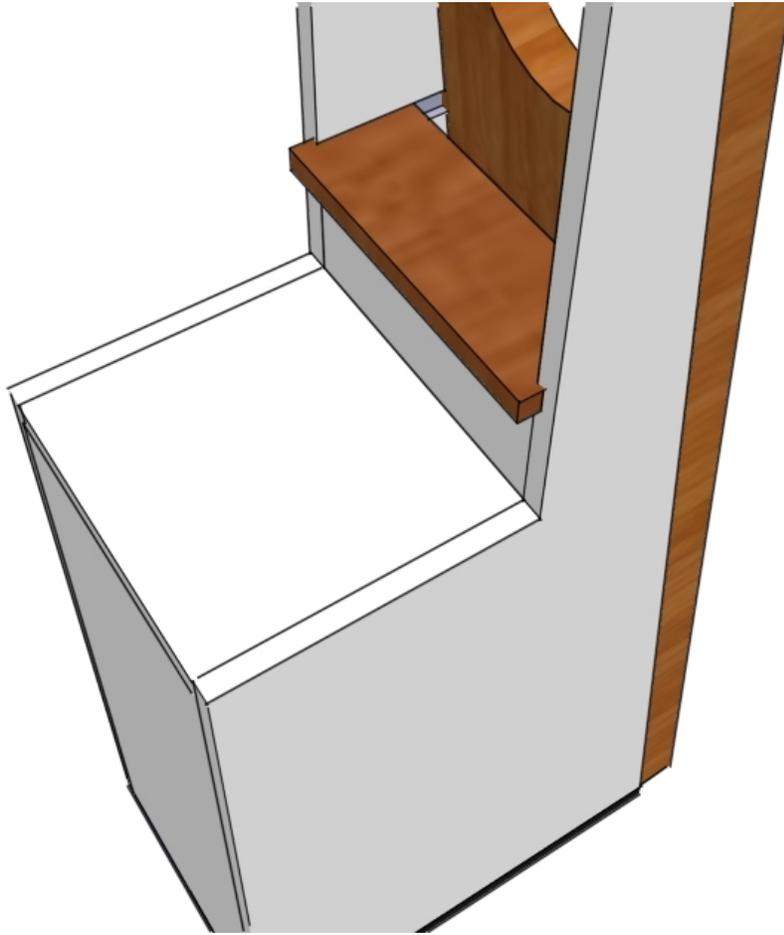
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Here is a transparent view... No drivers will be used inside the cabinet.

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Here is a view of the tuning slot just below the woofer. It allows you to tune the resonant cavity by ear while the speaker is playing. Shut this slot completely off and it becomes just another painful OB in desperate need of a sub or helping hand woofer somewhere.

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Here is a view of the drywall prototype with a modified FE206E installed.

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FIRST ATTEMPT OBSERVATIONS

The most fascinating part of this initial test was the slot itself. Closed and the whole cavity is deactivated, leaving you with a tiny completely bass-free open baffle for comparison sake. I found opening the slot took the hardness out of the midrange and the sound off the baffle. A massive improvement in midrange openness resulted...

The other thing that came as no real shock was that the bottom of the cavity had to be vented slightly to increase the efficiency of the cavity resonance. (At least on this model it did.)

Once the speaker was adjusted, I found the sound of it intoxicating. Not perfect, just doing several things better than I expected, thus intoxicating. I did notice during this time that some of the music had detectible bass that you could easily hear and feel. This was of course exciting, but other music that should have had bass was missing it. Since I hadn't even stuffed the cavity I expected a very narrow band typical of Helmholtz resonators. I just wanted to see how loud the resonance would be and if it would be enough. I expected it to drop a lot by the time I got the bandwidth wide enough to be usable.

After a few days of casual listening and playing with it I decided to see what it was actually doing so I got the frequency generator out and started sweeping. Results of the test were expected but still rather horrifying. There was no detectible bass at 100Hz. In fact there was no bass at 50Hz. There was only bass at 80Hz.

This was a good time for a long pause. I figured out that the widest Q that would still have enough output to be considered usable was still too narrow. It was starting to look like at least three resonators tuned 10Hz apart would be needed. This added level of complexity wasn't a terribly exciting option so with a bit more math I was able to talk myself out of it determining the dips between each peak would become noticeable only to some of us.

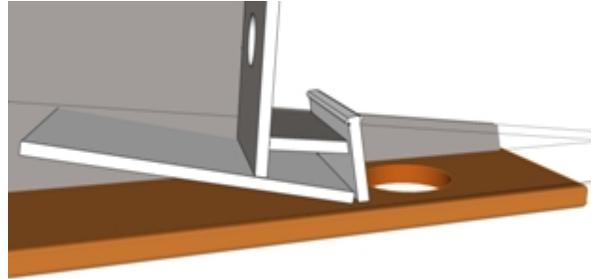
I really needed the rubber throat effect of a good horn flare to get the smooth flat bandwidth I wanted but had already determined there wasn't enough space. To that end I pondered another day and then decided to meditate on it. I put the cabinet on its side and lay on the floor staring into the open bottom of the cavity. After two hours of this I felt like I understood the cavity. After all, the formulas I used for complex neck designs were basically how to change the tuning of a given cavity without changing its size. Regrettably, as usual, there were no formulas that could model the ideas I wanted to try next.

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THE DESIGN THAT WORKS

In another evening's modifications, I created a *tapered* neck protruding into the cavity that terminated about 1/2 way down, with a narrow slot just behind the driver. This is how I intended to get the rubber throat effect I'm after rather than using a neck tuned at a center frequency. To make it work properly I created another small cavity with enough volume to fill half the area of the tapered flare. This smaller cavity acts as a capacitor storing enough air to feed the taper under resonance. This keeps the piston of air resonance from directly hitting the driver. Also the main cavity is vented with an 1/8" slot at the baffle through the base of the capacitor to help excite both by preventing a pressure drop in the capacitor, allowing it to grow in size on demand.



The final modifications included sealing the bottom of the main cavity and putting a round 3/4" long port at the top of the cavity to set the low frequency cut off point.

While listening to the modifications it was a thrill to discover this actually worked perfectly. The cavity now resonates with a flat response across over an octave between 40 and 80 Hz.

Unlike a ported speaker cabinet where the sound inside the cabinet is undesirable if you place your ear next to the port, this cavity sounds clear, not garbled, and contains exactly all of the musical information and low frequencies that are missing from the Open baffle part of the speaker. This in and of itself is rare and remarkable as far as I'm concerned. Part of the reason this is even possible is because the driver is not directly coupled to the cavity. There is no pressure exerted inside the cavity from the driver and the natural resonance of the cavity is at a very low amplitude leaving it distortion free when compared to speaker in a box that would cause the panels of the box to resonate (aka color/distort the sound).

These results by themselves when compared to a simple open baffle of the same size are most impressive. The difference in midrange and overall imaging are remarkable.

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LIVE BROADCAST

The final challenge is how to get the sound inside this cavity to equal the same level as the sound coming from the driver. If you listen to the port at the top of cavity with one ear it places the back of the driver only 12 inches away from your other ear. In this position the frequency balance is simply outstanding, sounding like you're hearing a live gig. The deep bass is wonderful.

Well obviously we can't stick our head down to the port to listen to the speaker so the most logical way to get the sound out of the box without increasing the pressure inside the box is to passively amplify it using a microphone feeding a second system. It might sound crazy, but provided the second system is done correctly, the purity of the design concept is preserved.

The mic feeds a good quality microphone preamp that feeds an amplifier matching the one driving the Open Baffle. This second amplifier drives a second set of cabinets capable of reproducing low bass notes. The second system will allow you to tweak the low end in several ways ensuring you have as much or as little weight as you want at any given time.

Why is this approach better or different than simply splitting the signal from your source into two separate systems? Read the part about harmonics again. Also understand that the second system is producing a **live broadcast** of the sound inside the cavity of the Open Baffle speaker.

As this project progresses and if we decide to manufacture it, the speakers would likely come with their own microphones pre-installed in the proper way and a stereo microphone preamp. It will be possible to get good results from supplying your own amplifier and speakers for the live broadcast. We will develop the whole system with matching electronics and synergistic broadcast cabinets to evaluate the design in the best possible light. At this stage of the game it becomes the next logical step.



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More explanations of this overall concept were given in the forums and re-posted below:

I suppose what's complex about how everyone else is doing it would be the result. Trying to get bass from a subwoofer and have it blend flawlessly with the driver in the open baffle is... complicated. Trying to fill a mid bass hole with a second woofer is... complicated. Trying to get the same imaging from a 15 as you would an 8 inch driver is... complicated. Harmonically handicapped might have been a better term.

While this is no less complicated from a gear perspective it retains honest harmonic integrity by presenting the amplifier with a single crossover-less driver that completes the full bandwidth from top to bottom. All the bass, mid, treble you hear are being reproduced by that driver. The low frequencies are sampled naturally by a separate resonant cavity and have no negative effect on the driver unlike a box where the low frequencies are creating high pressures against the cone and coloring its sound. And unlike a driver applying high pressures and high frequencies to a box (modifying the wave fronts inside the box), coloring the sound in the box. (This is why sound inside a speaker box always sounds garbled).

By separating the two, both the sound inside the cavity and the sound of the driver are uncolored. Getting the sound out of the cavity is where the live broadcast comes in. Using another set of speakers, a pair of mics and a good mic preamp allows us to hear the sound that is inside the cavity. Since this is mostly low frequencies we have to compare this approach with the conventional OB mated to a subwoofer, both fed from the same line level signal. In that approach, the subwoofer is reproducing the low frequencies from the recording. In this approach, the second speakers are broadcasting a live, pure analogue, direct feed from the cavity, not from the recording.

Careful matching of components, ie., the mic preamp, and power amp and speakers for the broadcast will of course determine how much better this approach is, but I have already tried it with random mid grade components and it is still clearly working better than when we turned off the cavity (by closing the slot) and used a subwoofer. The bass sounds real on the broadcast setup, even with all solid state gear because I tried that too. The bass does not sound as real on the subwoofer setup.

Besides the sheer strength of a live broadcast as a source vs. a CD player there is another big reason why this approach is proving better than closing the cavity and using a sub. It's the cavity. The cavity gives the OB wonderful tone and timbre. Without it, there is, among other things, an obvious lacking of something in the mid bass region. Depending on how accurately you adjusted the level on the sub, a frequency response chart would show a shelf in the response with a nice hole in the center of it. Regarding the texture and tone from the cavity, it's clearly audible without the broadcast speakers.

I'll admit this whole thing is a bit of a mind twister. It's been keeping me on my toes and in the dark. I'm sure it will prove to be very interesting as it develops. I'm anxious to get the entire set up completed for some serious evaluation when I'll be able to hear why this was a good or bad idea.

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ZEN OPEN BAFFLE SPEAKER PROJECT

PART II

By
Steve Deckert
OCTOBER 2007



As a continuation of [PART I](#) we have constructed a pair of these speakers based on the latest design (at left) that uses the more complex resonant cavity. The results greatly exceeded our expectations that were set by the first drywall prototype.

Because of the dominant hole in response between the driver and the cavity the original prototype was too handicapped to be listened to by itself. When the cavity was miked and or a subwoofer was used and crossed over above 100 Hz, the speakers sounded well balanced.

In the new design, the hole in response has been eliminated and the tuning of the cavity did not have to be raised. This was a pleasant surprise. It was hoped that the new cavity design would lessen the severity of the hole, but that it worked so well was unexpected!

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TESTING

Above are the new Zen Open Baffle speakers. They were measured as you see them in the above set up. The first step with these was to become familiar with them on their own, no subs or fancy broadcast setup for the resonant cavities. I sat down expecting to hear basically zero bass and that was ok because I really wanted to hear if we got the textures in the midrange right. *Remember the cavity is primarily to open up the sound of the midrange and support it with compatible harmonics.* Shutting the adjustable slot below the driver confirms that placing a driver in a plane board is a dry almost lifeless sound by comparison.

As I started to listen I was immediately taken by what I heard. In fact I got so swept up in it that it was probably 10 minutes before I remembered that I was suppose to be listening to a speaker with no bass.

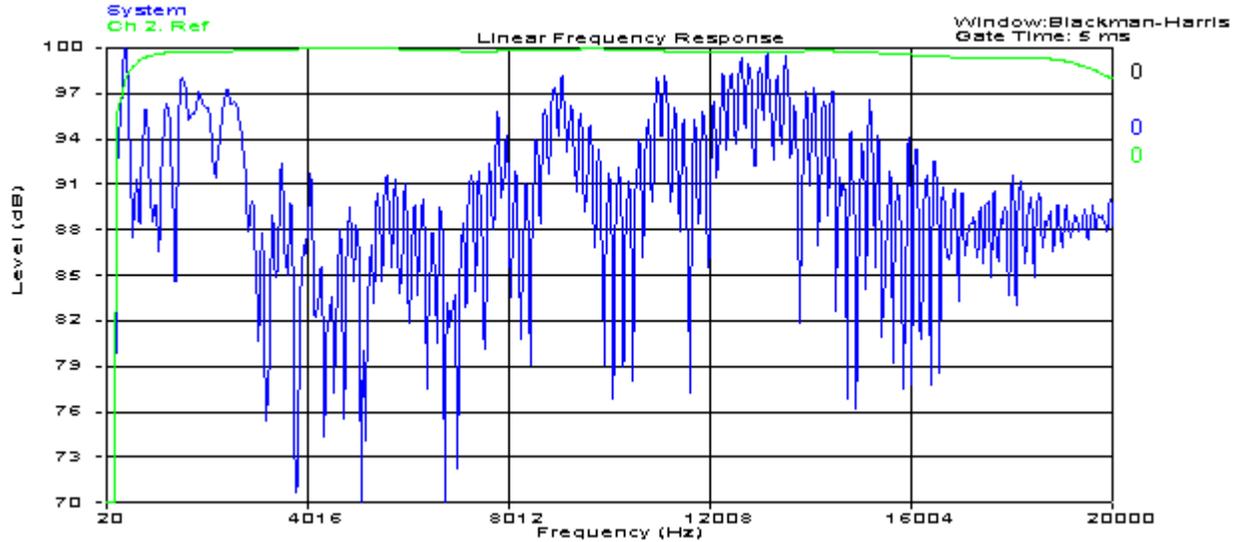
Since I was listening to acoustic music there wasn't a lot of bass in the recordings and I remember sitting there thinking that what I was hearing sounded simply great, not thin at all. About then a tympani drum was struck in the recording I was listening to and I felt the percussion of it in my chest. Now wait a minute - I thought... as I started to double check all the other gear in the room to make sure I hadn't somehow accidentally left a sub on somewhere.

Needless it to say, there was somehow bass coming out of these speakers without having to mike the cavity or use a sub. Not a lot of bass mind you, but enough to get the job done and it seemed like a lot when you're expecting none. I listened somewhat captivated for the next couple hours waiting for some recording to reveal a hole in the response that I expected to be there but it just didn't happen. Everything sounded fine. A couple nights later I listened again with some of my best recordings and accidentally sat there until 4:00 A.M..

I could really go on and on about what I heard. Insane imaging, insane soundstage, insane detail, insane timbre and overall tonality was near perfect. Now it was time to measure these things and see what is really happening here.

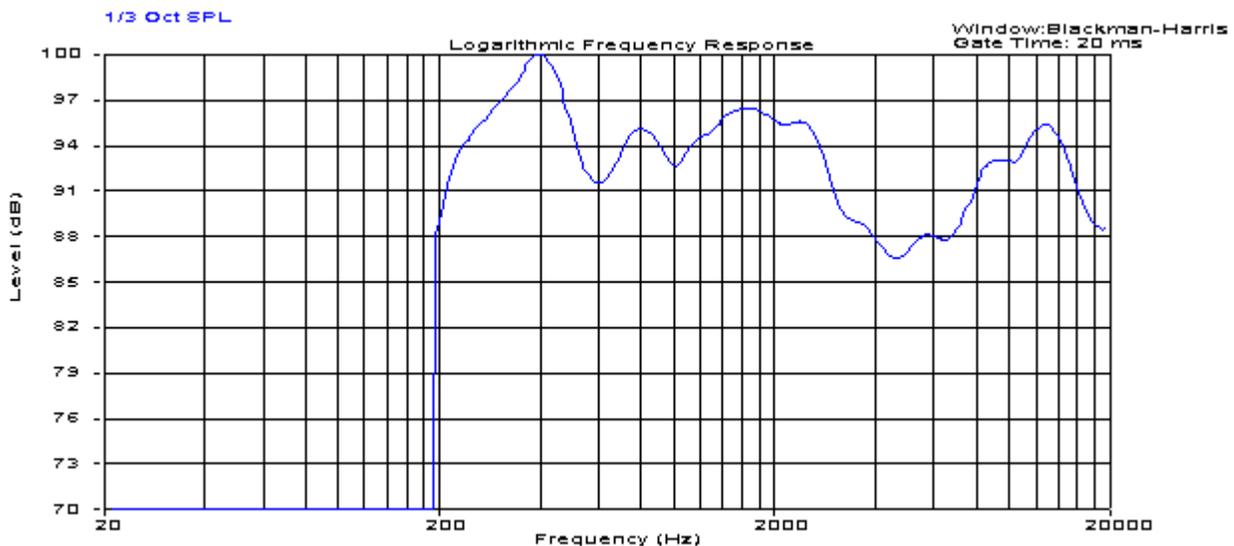
Is it possible that an open baffle speaker of such a small narrow stature is actually developing bass when it should be taking a nose dive before it even hits 100 Hz?

MEASUREMENTS



The first measurement I always like to do is one with the mike behind my ear while in the listening chair. This shows me the room response and what I am hearing at the listening chair that I felt sounded so damn good. It makes a good point of reference as a first measurement.

Here is the logarithmic response from the same measurement. Note these are measured from 200 Hz to 20KHZ.

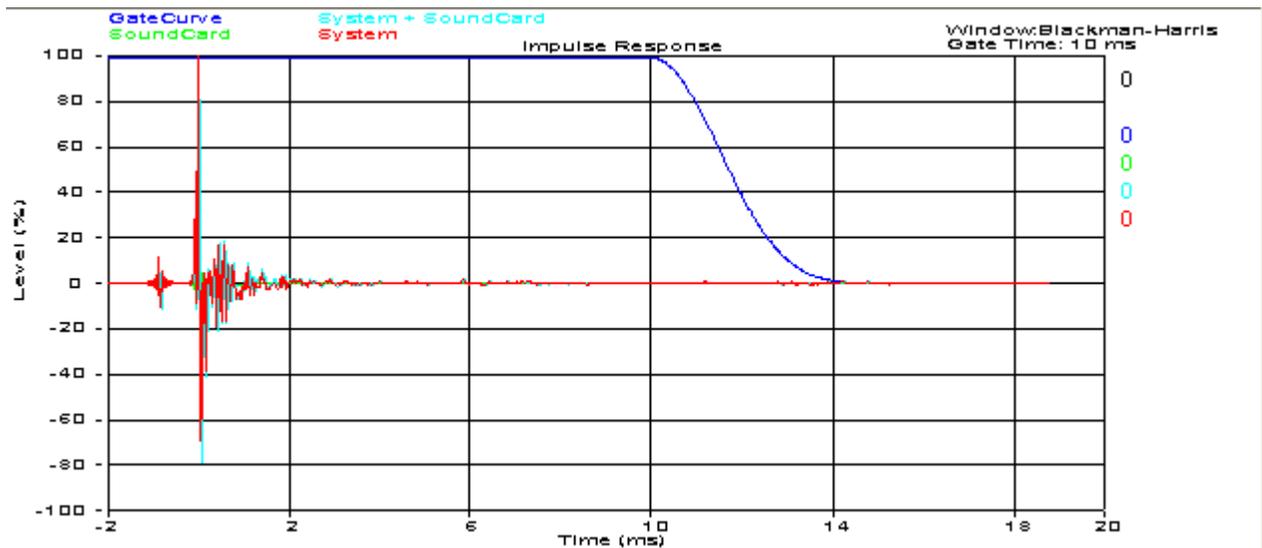


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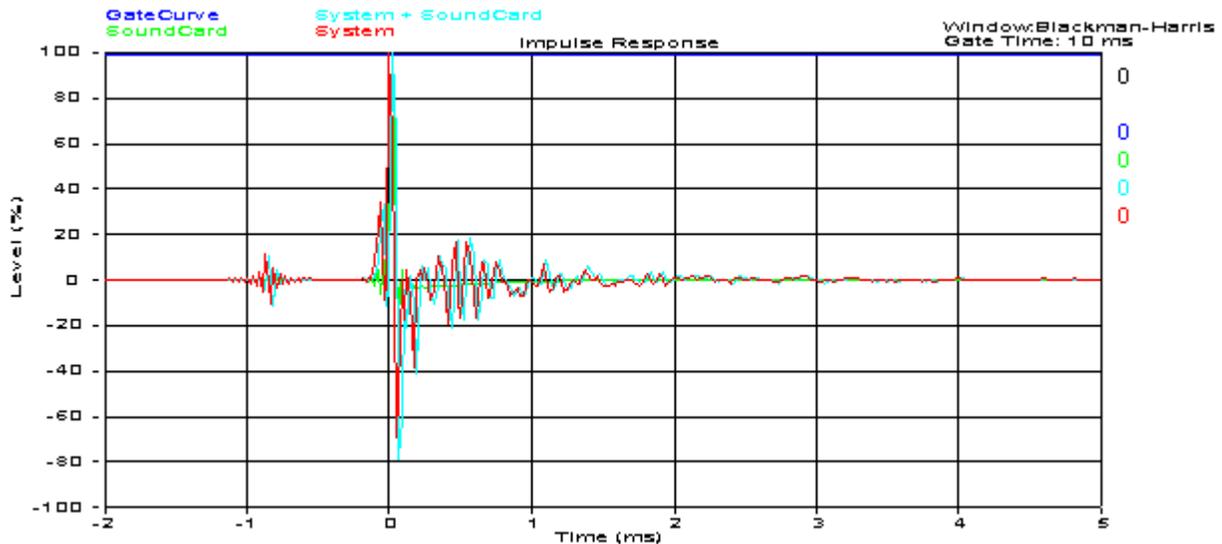
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It is wise not to get hung up on how flat or not flat it appears as this is also from the listening chair, not in an anechoic chamber.

Now that I know what the response I'm hearing at the chair looks like, it's time to measure just one of the speakers at a distance of 12 inches to take more of the room effects out of the picture. The first measurement I took was the impulse response. This is actually the quickest settling time of any prior tests I've done on speakers in cabinets. Pretty impressive.



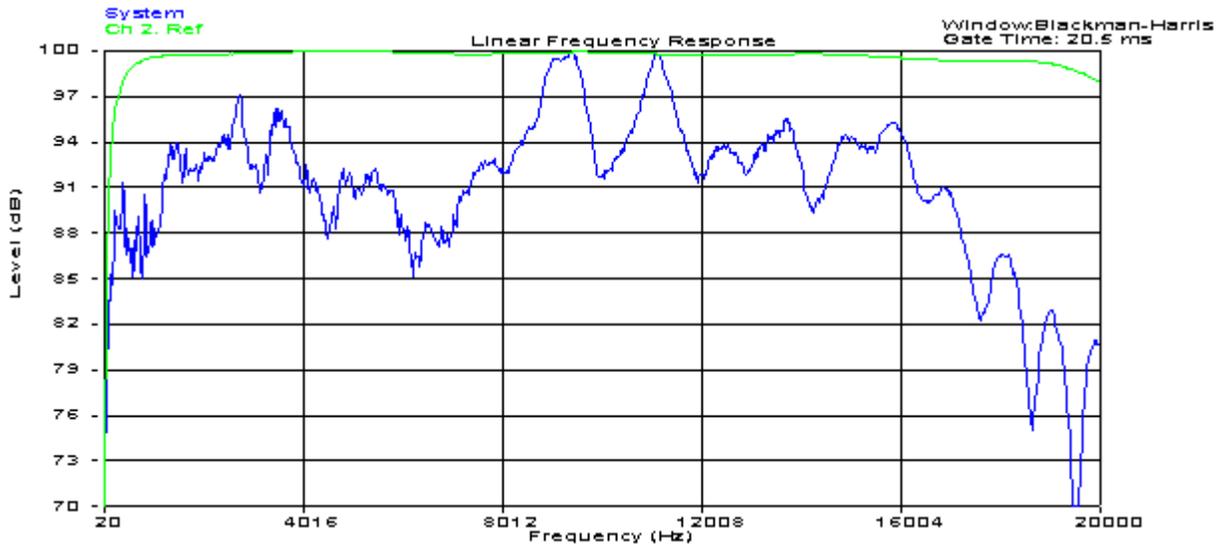
Below is the same test focusing on the first couple milliseconds so you can see how quick this speaker is.



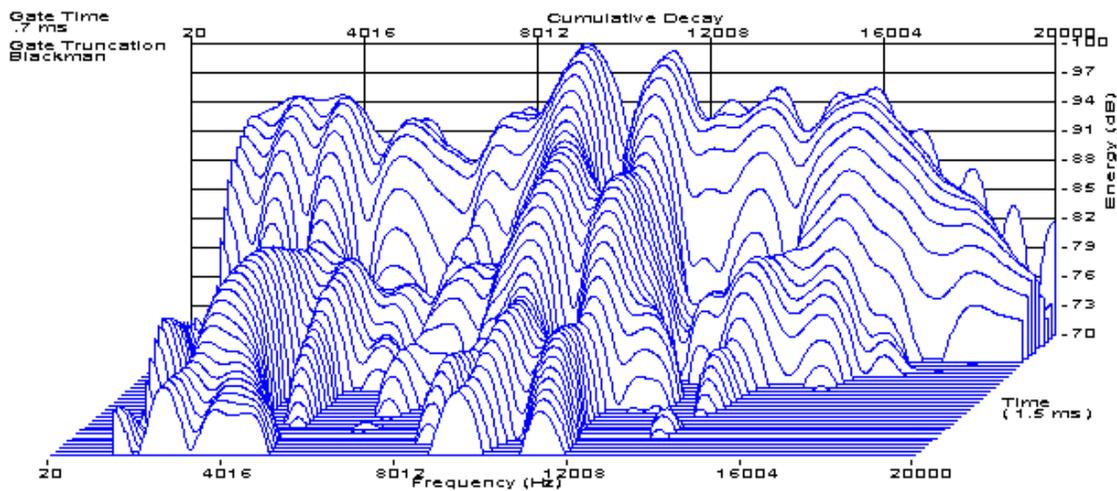
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The electrical signal is the green line. The speaker is the red line. The speaker is tracking the electrical signal perfectly.



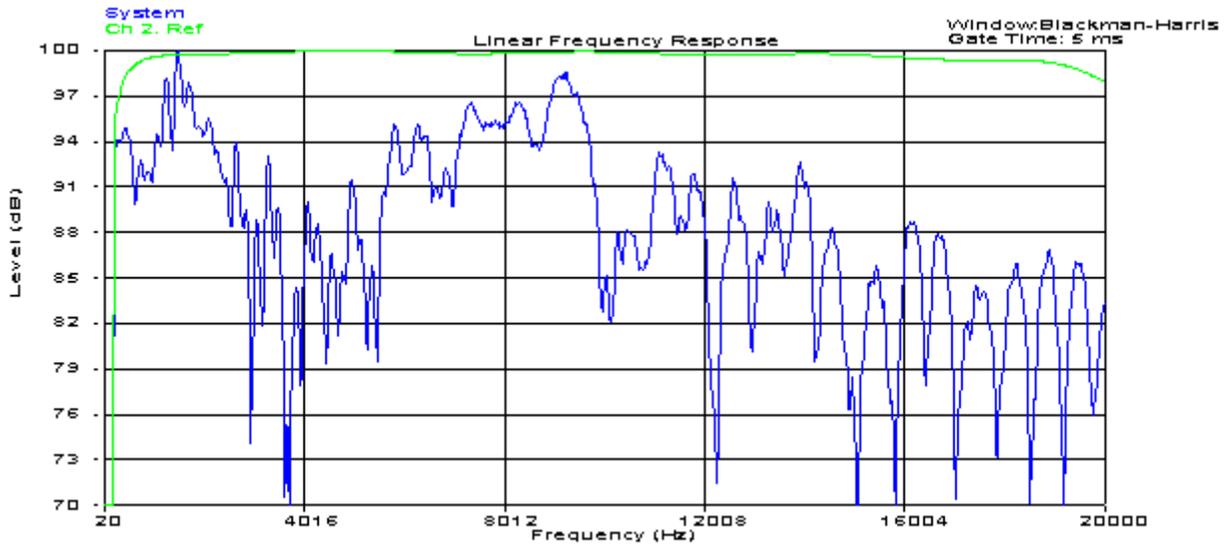
Here is the linear frequency response at 12 inches at 0 degrees axis. The two peaks between 8012 and 12008 Hz are not really there in the listening chair because the speakers are toed several degrees off axis for listening. I'll show the same response later at 30 degrees for comparison. Below is the cumulative display of the same measurement as above.



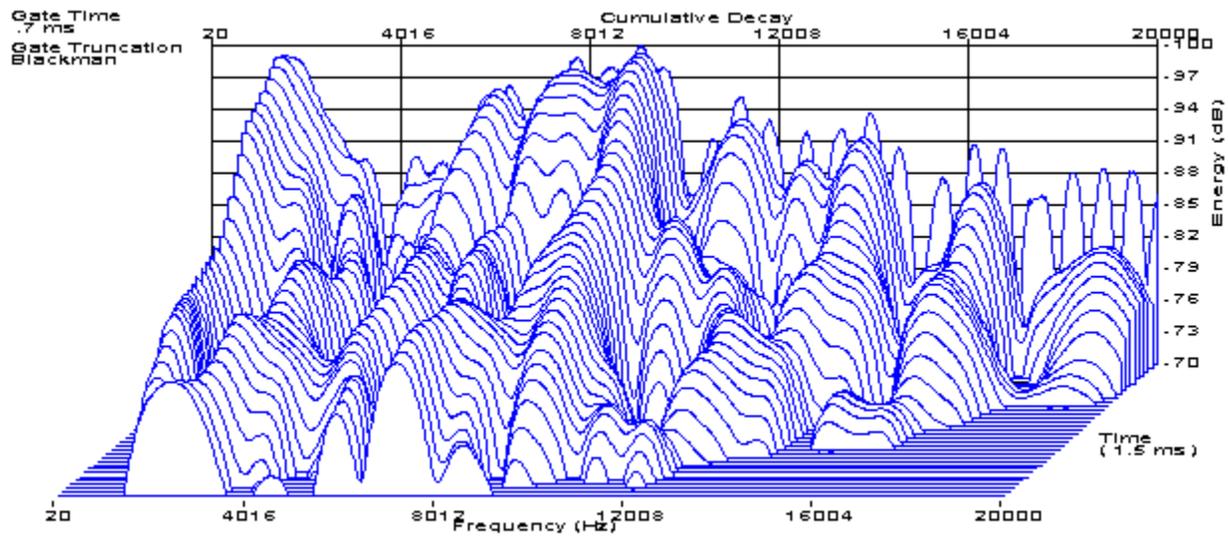
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Here is the linear response at 12 inches like above, but at 30 degrees off axis.



And the cumulative display of the same measurement is below.

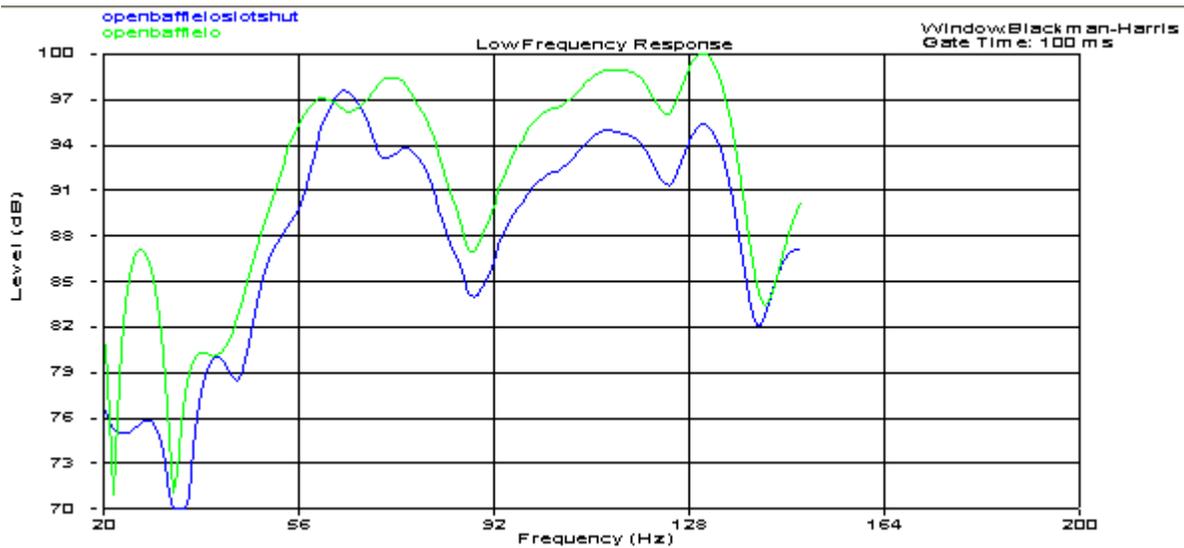


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LOW FREQUENCY RESPONSE

Below is the low frequency response back at the listening chair. The 90 Hz dip is in part caused by a room mode at the chair.

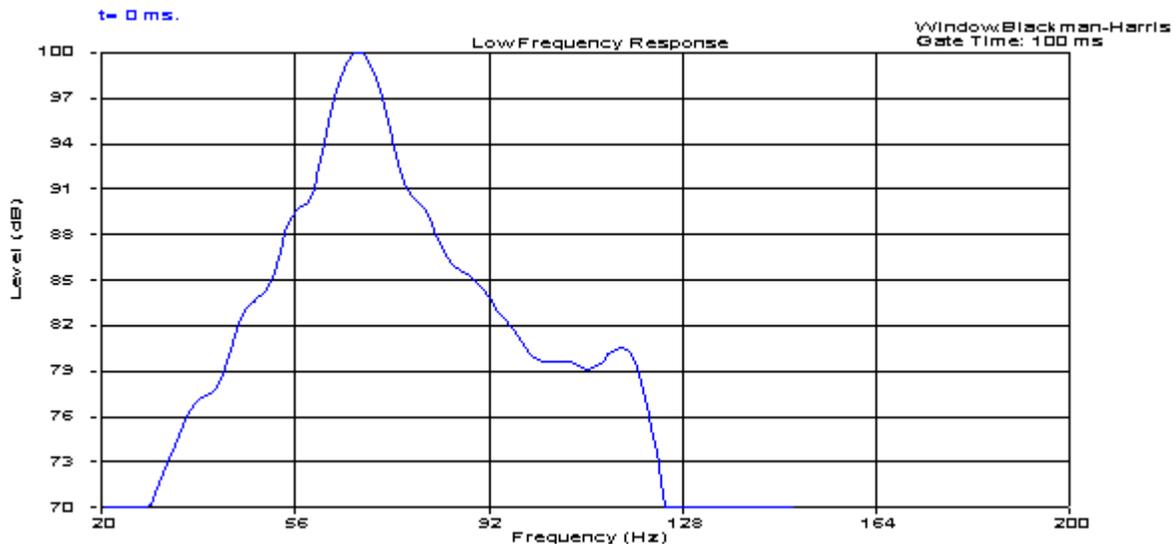


The blue line is with the tuning slot closed. As you can see there is still a good amount of coupling between the cavity and the driver even when the slot is closed. The port opening at the top of the cavity combined with the direct energy that is transferred from the baffle to the cavity is what is responsible for this. The green line is with the tuning slot opened and tuned for the best sound. I forgot to do a low frequency measurement at 12 inches but when you consider that a speaker in a board that is fully open with no box should be a line starting at about 150Hz (where it starts on the graph) going straight down and off the chart by 128Hz I didn't see omitting this finale 12 inch measurement as a real problem.

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The next and final measurement is of the cavity itself. This taken at point blank range at the port of the cavity.



THE FINAL CONCLUSION:

We have a crossoverless single DFR8 full range driver in an open baffle speaker that is 12 inches wide developing bass response down to 52 Hz with no assistance from other drivers. Pretty safe to say this has never been done before. It clearly meets my original design goal of maintaining the absolute purity of a single driver, getting bass response without needing a second larger driver (as so many open baffle designs do) and getting the correct timbre and texture in the midrange that no other open baffle design will have due to being an open baffle.

The speaker in my opinion has the cleanest bass response I've heard to date only being rivaled by my reference Acoustats. On acoustic, new age, vocals, and similar kinds of music I find it intoxicating. On rock it is as you would expect, a little too lean.

The best part of the surprising performance of this design is that A) it can be enjoyed stand alone and B) it can be used with your typical sub. I fully expected this design to require a broadcast system to be usable.

A system that would include 2 high quality microphones, a high quality microphone preamp, a second stereo amplifier and a second pair of woofers in their own respective cabinets placed somewhere in the room.

I intend to continue to implement the broadcast system to see what happens, but it now clearly becomes optional for those who have the money and want to pursue it.

Steve Deckert



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ZEN OPEN BAFFLE SPEAKER PROJECT

PART III
by
Steve Deckert
APRIL 2008

In the final conclusion of part II, I said:

"The best part of the surprising performance of this design is that A) it can be enjoyed stand-alone and B) it can be used with your typical sub. I fully expected this design to require a broadcast system to be usable. A system that would include 2 high quality microphones, a high quality microphone preamp, a second stereo amplifier and a second pair of woofers in their own respective cabinets placed somewhere in the room.

I intend to continue to implement the broadcast system to see what happens, but it now clearly becomes optional for those who have the money and want to pursue it."

REVISED STATEMENT:

A) it can be enjoyed stand-alone on certain music sounding better than real while sounding painfully thin on certain music. B) it can be used with your typical sub, yes. However, when implemented true to it's original design concept with the broadcast section both A and B would by comparison sound like a complete joke. Therefore while it could be used stand alone if you don't like a lot of bass, or with a sub, after hearing it with the intended broadcast system we will officially discourage both A and B !!!

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ITS NOW APRIL 2008

After taking 6 months off and deliberately not listening to these speakers I was feeling in a far more objective mood than when I left off. Allowing the proud papa syndrome to wear off as well as the desire to have this speaker fly stand-alone, I was ready to pick up where I left off and give these things a real objective listen once again as stand alone open baffles.

I used stock CD player as a source - this will handicap things a bit and let me hear what the worse case scenario is going to be. I picked up a Neil Diamond CD that I knew didn't have a bass heavy mix, in fact typical of many rock recordings it always sounds thin on any system. (*Side note: because of this I have never taken the CD seriously and rarely ever played it.)

I put one of my 6 watt triodes on them and let it warm up for a bit. My ears are now someone else's (a nifty side effect of taking 6 months off to see if you still like something) and I'm ready to hear everything wrong with it.

I plop the disk in and press play. Now trying not to like them I had to admit the clarity was surprising. However this thin sounding recording was just screaming for some meat on it's bones. Within 3 or 4 minutes I had made a clear decision that this wasn't going to fly and turned it off. A few minutes later after some disgust wore off I turned it back on because I wanted to hear the sound inside the cavity again. I placed my ear near the opening and was instantly entranced by how rich and clean the bass lines were and found myself really enjoying the CD.

THE DECISION TO MOVE FORWARD

I think my exact words to myself were something along the lines of "quick screwing around and finish the damn project so you can hear it work" Yes, let's stick to the original design and complete it. On to the broadcast system.

THE BROADCAST SYSTEM

This is where things get really interesting so if you've read this far, you'll probably want to continue. Again, to experience worse case (real world) performance rather than use \$600.00 microphones on exotic tube mike preamps, I dug up some cheap Audix drum mikes and fed them into a \$200 Berringer mixer feeding an old Ross solid state amp. If this concept actually works as well as I predicted - it should have livable results even with junk gear. If the test fails or sounds like crap with the junk gear than something is fundamentally wrong and the best good gear would do is make it almost right.

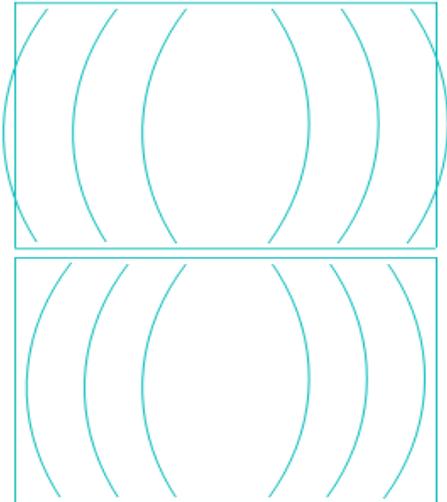
LETS TALK ABOUT REAL SOUNDING BASS - EPIPHANY NO. 1

■ DECWARE

AUDIO WHITE PAPER

While setting the up the electronics for the broadcast system I made several fascinating discoveries and actually had a couple of epiphany's that I'll never forget. The first epiphany came after listening to the non-compressed natural bass of the cavity against the same thing coming out of a pair of typical box speakers. This comparison would be all but impossible for most audiophiles to make because you would need a cavity design that closely copied the Zen Open Baffle and to date the design hasn't been released so nobody has one.

I've spent 30 years listening to box speakers of all kinds as well as every other kind and well understand the colorations associated with boxes. My [full range direct driven Acoustats](#) make all but the very best box speakers sound silly and the most obvious difference shows up in the bass clarity. That coloration werew hear with boxes is gone. I've designed a few speakers and up until this design I thought that coloration was cabinet resonance and the standing waves inside the cabinet etc.



What I realized is that the pressure created during lower frequency cone excursions not only compresses the air inside the cabinet but also seems to be compressing the distance between wavefronts and changing the pitch. These altered waveforms work against the cone causing smearing across the original phase angles of the driver. They also slow it down.

The resonant cavity of the Zen Open Baffle has roughly 1/10th of the energy in it's panels as it would if there were a driver mounted in it like any box speaker. Therefore when you hear the sound inside the cavity, there is no distortion from panel resonance to be heard.

There is also almost zero pressure inside the cavity so the sound inside is not aggravated or compressed by the pressure.

Unlike a box speaker, even with the worlds best crossover, there will be sound inside the cabinet that falls well above the cabinets resonant frequency. These mid's and low level highs inside box speakers leak out of the ports and through the speaker cone and by the time they leave the cabinet through either of these two mediums their phase angles no longer match the wavefront coming off the front of the cone. This is where open baffle speakers have such an advantage. There is no pressure, and there is no cabinet to poison the speaker cone. However, open baffles have no bass per say unless using multiple drivers or large drivers in large baffles. That means most open baffle speaker systems use a sub that can't sound as good as the open baffle because it's in a box. It also means that if your not doing that, you've lost your single point source by using more than 1 driver and along with it probably small size making the front of the baffle nothing more than a large sound mirror for reflecting sound from the room back to the listener - making it hard for the speakers to completely disappear. If you kill the point source conflict from multiple drivers by pasively crossing one over to reproduce only low frequencies, then you have poluted the puzzle with a crossover.

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The bass inside the resonant cavity of the Zen Open Baffle is seeded by the [single 8 inch full range driver \(DFR-8\)](#). That means the sound inside the cavity is virgin or pure in the sense that some other driver or electronics or both didn't create it. Because of this, it is seamless and perfect in its coherency with the main driver - on an order of magnitude better than the best implemented subs (which I have).

THE HIGH DEFINITION BROADCAST SPEAKERS

It is impossible for a typical box speaker to reproduce bass as realistically or accurately as the bass that is found inside the cavity. Again, the only thing that sounds like what's in the cavity are my Acoustats / but to own something as good today would start at \$100,000 and require a large room and your willingness to live inside the sweet spot.

Provided the sound inside the cavity is properly broadcast into the listening space it would be like hearing the single 8 inch full range driver's own bass in any proportion necessary to achieve the desired frequency balance. The trick to that is the transducer. The speakers used for the broadcast need to be anything but a conventional box speaker and capable of the incredible speed that is only possible in an enclosure by having nearly perfect dampening like a straight horn. Regrettably such a device would be too large too expensive and create room treatment issues just by its size. The only other design up to the task is the HDT cabinet because of its tremendous speed. The HDT cabinet is a cross coupled multi-chamber design with 5 tuning frequencies across over 2 octaves creating a death grip on the woofer cone. The wide band dampening makes it one of the most linear box designs I know of. If we used anything less, such as a simple reflex cabinet, be it sealed or ported, its own colorations would mask the beauty of the cavity sound to the degree where you would lose 90% of the benefit.

With the HDT's used as the broadcast speakers it is possible to accurately capture the magic of the cavity and seamlessly allow it to escape into the listening space. The broadcast signal is relative to the mic placement, type and so on. The mic will pick up background levels of high frequency information coming off the rear of the driver as tiny amounts are entering the cavity. This allows a natural shelf to develop between the low frequencies of the cavity and the cut off of the driver in its baffle. By having this small trace of full range ambient sound up to about 5kHz and between 12db and 18dB down from the reference level of the Zen Open Baffles, the harmonics of the bass lines in the recording remain in tact from both positions on the arc. I'll talk about the arc soon. Anyway this is not possible with a sub approach and I find it to open up the music in a way so vivid that it has me questioning my Acoustats. I believe this must be a pretty natural form of desirable ambience in just the right trace amounts to lock in some really jaw dropping playback.

LET'S TALK ABOUT HOLOGRAPHIC IMAGING - EPIPHANY 2

A few people I know have been fortunate enough to build a pair of Imperial SO's and use them as the bottom end behind a pair of good box speakers. Not just for reference quality 20 cycle on up response but because of what it does to the imaging and scale of their main speakers. It takes the sound stage and explodes it in size and makes everything sound more logical and coherent. The imaging always appears far more organized and locked in space giving breath taking focus. You can see them behind the Zen Open Baffles in the picture below. Over the years I've tried more speakers in front of these 28 cubic foot horns than I can remember, and the majority of them gained this superior imaging and scale every time.

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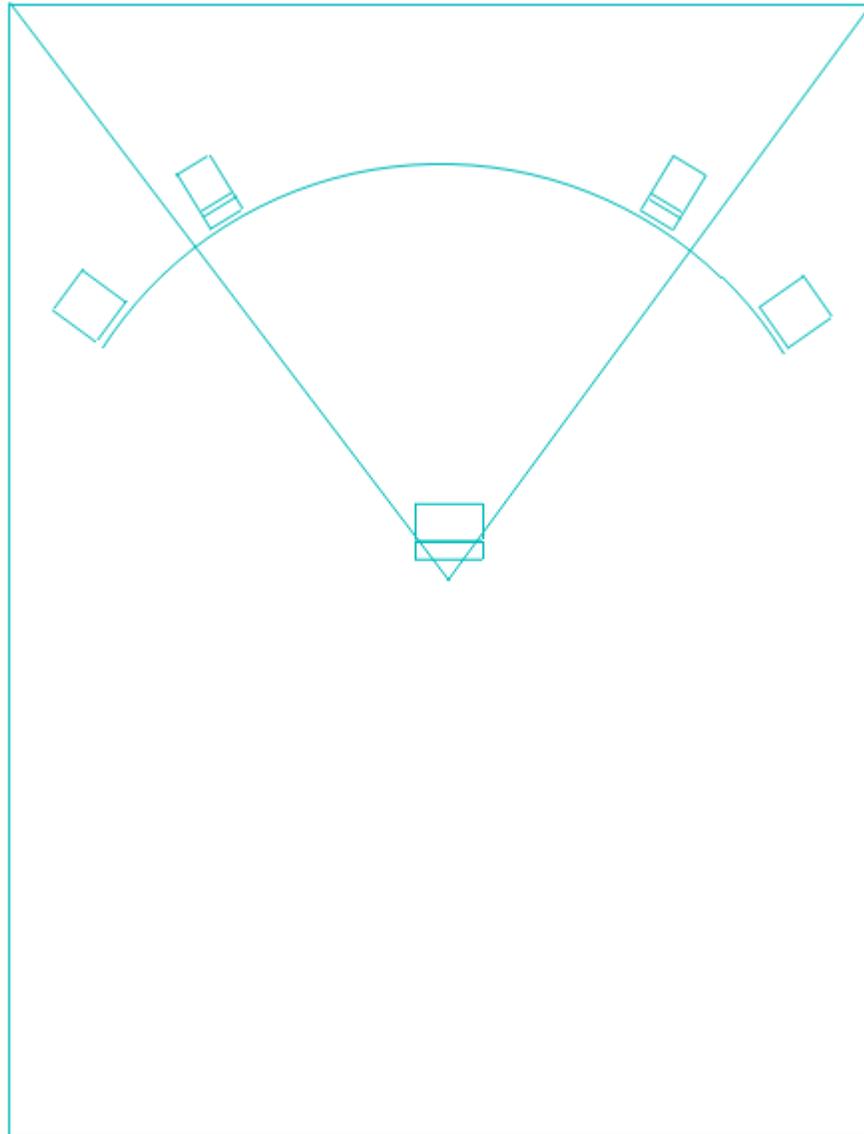
The scale in particular I've always attributed to the size of the wavefronts from these big monsters, and the imaging I theorized was the result of the mid and high frequencies being somehow organized by the large fundamental wavefronts. I was apparently wrong on both counts.

Finding the perfect placement for the broadcast speakers (HDT's) turned out to be on the outside edges of my listening arc. That put them about 1 foot away from the walls, but towed in true to the arc as are the open baffles. The picture below shows the 115 degree arc proportional in my listening space.

Once I got this set up and listened to it I realized quickly that I was getting the same sense of scale and improved imaging as I did with the Imperials on other speakers. In fact the sound was so similar it was like having the imperials on. There was one difference that stood out, and that was the imaging and something absolutely magic about the bass. Far and away the cleanest, most open natural sounding bass, and fast, fast, fast. Deep and Rich with non-congested weight and scale that made the presentation far superior to the imperials in combination with these or any other speakers I've tried - something I never expected to top. Yes, it was the magic of the cavity and the implimentation of the arc that took the bass to this new reference level.

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So this blew my theory about the large wavefronts somehow organizing the mids and highs into a more coherent 3D image. The epiphany was realizing it's the *width cues* that we get in real life that are missing in almost all 2 speaker setups. Low frequencies that emanate from the same location as mid and high frequencies in real life, such as a band, always find the boundaries of the venue and wrap back in on the listener so the ear expects to hear these low frequencies come at it from the sides and arced back to the center. If the listening arc is too small, this is impossible.

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Using two subwoofers placed at the outsides of the arc will not accomplish the effect I am hearing. The speakers must be able to coherently play not only the low frequency information at the same level as the Zen Open Baffles but also reproduce the harmonics of those low frequency's for at least 8 octaves with high frequency content at background levels. Then there is the natural ambience of those frequencies that escaped from the main driver into the opening of the cavity to consider. This is the source of the high frequency content.

The unbelievably real imaging... perhaps it's the width cue that releases the brain from processing why information is missing from this area and lets it better process what is at the focal points.

What's interesting is that the Zen Open Baffles do a fantastic job of imaging by themselves, but when the broadcast is added it simply transforms the imaging of the ZOB to jaw dropping heights and floats in the room independent of the speakers and regardless of where you sit or stand. It's just happening. In that respect it is performing like our [Radial design](#).

It should be understood also that you do not hear the broadcast speakers until you get your ear around 1 foot away from them, so they are never directly noticed. I've had several people listen to the setup without knowing anything about it and no one realized the broadcast speakers were on. Their level is of course adjustable based on the gain setting of the broadcast amp giving us a much needed tone control for listening to lean recordings. You can have as much or as little weight as you want, the imaging remains unchanged. Adding a little extra weight to a recording in this manner does not thicken up the bass or mud it up like it tends to on typical box speakers. Regardless of the level you are struck by how incredibly clean and open the bass is, and how richly it layers out without ever showing even the slightest hint of strain or compression or distortion.

SUMMARY

The only way to really present this design is in it's entirety. It is a 4 speaker system. ZOB for the mains and [a pair of HDT's](#) for the broadcast. And when marveling at this combo it occurs to me that I have never heard my amplifiers sound this good and since the sound you will hear from this design will only be as good as the weakest link, it makes sense to also offer a 4 channel amplifier with a built in microphone preamp (all tubes) to run it. That is my next step, developing the electronics. I have every confidence that this system would represent the flagship of everything I've done to date so it should be approached from that perspective. Someone who wants the very best there is...

I've already been bombarded with the knee jerk statement, yea but its... four speakers! Like this is somehow a problem. My response is always the same... you already probably have 2 pairs of speakers in your possession now, yet you can only enjoy one pair at a time. Sell it all up and try this, it's the best way I know to make every dollar you've spent on audio gear count for something.

PLANS

Since it is possible to have good results with lower cost electronics for the broadcast, anyone owning a great sounding amplifier and willing to build their own ZOB array from plans will have an opportunity at the completion of this project.

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The new name for this project is now going to be called:

THE ZEN OPEN BAFFLE ARRAY.

* BTW: The Neal Diamond CD turned from a less than pleasing recording that was avoided for years into an absolutely incredible sounding live experience. It felt and sounded totally real when played on the array and turned out to be a most impressive recording. Finally a system that can make everything sound right. Instead of listening to 10% of my music collection I can now enjoy 90% of it. When you can strike the right frequency balance, it is surprising how many bad recordings were actually quite good.

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ZEN OPEN BAFFLE SPEAKER PROJECT

PART IV

by

Steve Deckert
OCTOBER 2008

As I've probably mentioned in early parts of this paper, when designing something new like this, I like for it to take a long time. Between each step in development I like to put the project on ice for at least several months. I like to do this because each time I thaw it out and get back into it, I see it as if I was a different person. This eliminates infatuation and proud papa syndrome and breaks any desire to stay on the same road I was on when I stopped. You know, things in motion tend to want to stay in motion.

In Part 3 of this paper I had reached a point where I was happy enough with the results for myself but worried about making it user friendly enough to publish or sell. So after Part 3 was written I put the project on ice. Above is a photo taken in my then unfinished listening room with the speakers set up as they were in Part 3. The broadcast speakers (HDTs) are just out of the frame on either side of the Open Baffles.

Meanwhile I had a listening room to complete before I could continue any honest evaluations. (I also had to bring the listening room to near completion because it's been on ice since last year's DECFEST). My plan was simple. Get the room done, and during Decfest, set the system up and demo it. It will be the first time I've heard it since I put it on ice after part 3. That should put some substantial pressure on me, and an excellent real world test. It's either going to bomb badly or it's not.



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Something did happen to the speakers themselves while they were on ice. I robbed one of the drivers to help a desperate audiophile out in a time of need. I had been using our DFR8 full range driver but wanted to try the shielded version of the DFR8 in these cabinets since it has a much more streamline magnet assembly shown above.

Naturally since the speakers were on ice, and I'm a man cursed with having to wear too many hats, I waited until a few nights before the DECFEST and built a new pair of shielded DFR8s. I then bench-tested them and that was it. Yes, believe it or not I'm going to present the ZOB at the fest using brand new drivers with a total burn in of 10 minutes. I figure if the ZOB impresses with these handicaps in place then I'm solidly on track with the design.

The fest finally came and I set up ZOB just as it had been before, only the room around it has been largely finished. BTW, I didn't get to complete the room until three nights before the fest so I had no idea what to expect from anything we heard in there.

With a room packed full of onlookers, I set up the microphones and was concerned about trying very hard NOT to set the gain too high so as to spare us all the horrible sound of low frequency feedback. So by the time I had music playing so that I could blend in the broadcast speakers - and I remember thinking how odd it was that I was already hearing plenty of bass and hadn't yet turned the broadcast on! Well, no time to process that so I turned on the broadcast speakers with less gain than I recall from before, putting me farther away from the yellow zone of potential feedback or booming. That was a good thing, I could relax.

My listening to them was only brief enough to make sure that nothing sounded bad, and then I continued to mingle with everyone. It did sound really good. Smooth with nice weight. The broadcast was completely transparent. The frequency balance seemed better than before. I noticed they remained set up and in use for a very long time meaning they were able to hold peoples attention better than other speakers. In a fest environment holding anyone's attention more than several minutes is hard to do if you're a speaker or an amplifier!

So I considered the first real world test a success. I set the ZOB up exactly as I had it at the end of part 3 of this paper and let about 40 people listen to it without my intervention or presence in the room.



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Again, the ZOB was put on ice directly after the fest until some three weeks later when I decided to use them one evening at the other end of the listening room... shown above. I wanted to hear them by themselves again - without the broadcast system. So I set them up at the other end of the room and there it was again - body! Way more than I remembered at the end of Part 3. I spent an evening with them rotating amps and sources. There was far less of a gap between the resonant chamber and the driver roll off. In fact, the holes that were there in the past (that were so nicely filled in with broadcast speakers) were filled in enough that I'll have to perform measurements it to see if they are still there at all. The overall Q of the chamber has lowered (flattened) too. I'm getting plenty of usable bass at 40 cycles. After two more repeat nights of conformational listening on good recordings and some daytime listening on horrible recordings I can conclude the following things:

- A) The speaker is now usable on its own - something I had given up on for the most part.
- B) The bass is largely absent below 40 Hz, but above this it is full and incredibly flat sounding. It's hard, if not impossible, to aggravate it with complex bass lines. This is absolutely the cleanest bass I've ever heard next to my Acoustats.
- C) Imaging varies with sources and recordings more than it does with other speakers.
- D) Imaging ranges from one to six feet outside the speakers and between eight and 30 feet to the back limit of the sound stage. Presence and detail are almost in a new league, may even be a benchmark.
- E) Good recordings sound good. Great recordings sound completely real depending on the source used. Bad recordings get thin sounding, making the speakers seem too present.
- F) A foam tile was temporarily placed below the driver on the face of the baffle. This produced a noticeable improvement in midrange smoothness. (The room presently has a concrete floor with a small area rug.)



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G) A foam tile was temporarily placed behind the driver on top of the adjustable slot panel to create more division between the port and the rear wave of the speaker. It seemed to improve the coupling between the driver and the chamber below.

H) A two watt Zen Triode amplifier has a much weight as the 25 watt Torii MK II with these speakers, or put another way, the bass (frequency balance) of each sounds about the same. On the box speakers, a Torii MK II will usually develop noticeably more visceral bass than a Zen Triode. Also for most of my listening, the playback level was the same for both amps. I used the TORII MK II for the majority of my listening simply because it is a less forgiving amplifier and also because it is capable of complex feats of effortlessness in classical music at louder playback levels. A great amplifier to judge how good a speaker really is.

I) With the exception of my Acoustats, never before had I experienced such a wide gap between the sound quality of different sources and recordings. This is consistent with past experiences in that when an audio system gets too transparent, the contrast between good and great recordings becomes so huge that you can only bear to listen to your best recordings, substantially reducing the content of your music library.

THEN CAME THE IMPERIAL BROADCAST

After spending a week with the open baffles all by themselves, I wanted to hear what they would do with the broadcast system added again. However, this time after some study of the room I realized I might be able to use my Imperial SO horns at the opposite end of the room to effect a similar wave front at the arc of the speakers by just jacking with the phase angle.



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I set up a two-watt Zen amp to drive the Imperials (shown above) and re-installed the microphones in the open baffle cabinets. Remember, now more than ever, the broadcast system is an ambience tool with the added benefit of introducing a controllable amount of weight and scale to the playback. (Before, it was almost a requirement just to have a usable frequency balance.) The broadcast has shifted from a requirement to a luxury.

I got lucky with the phase angle and the wavefront from the Imperial SO cabinets, and if you study the room shape you may be able to see why this worked so well. The broadcast system is turned on but just to the point of being detectable no more. I don't want to be aware of the broadcast speakers in the listening position or anywhere in the room as I walk around. This is how it was set up in part 3 when I used the HDT MK IIs as the broadcast speakers.

Below is a picture of the the right Open Baffle speaker and to right the HDT used as the broadcast speaker. The unused Imperial SO is the large cabinet that looks as if it is built into the wall behind the open baffle speaker. This is how I set it up for the show, and this is the back of the room. When the time came to demo the ZOB all I had to do was turn the couch around.

Activating the Imperial SOs in this way with speakers at the opposing end of the room has a wonderful effect on the rooms acoustics, creating a flat bass response throughout the dead center of the room with no holes and even all the way out to the boundaries. This acoustic correction effect makes the open baffles appear to have better bass, as you might expect, so a very symbiotic relationship results between the driver in the open baffle and the room.

SO HOW DOES IT SOUND?

The sound stage has pushed back to whatever the recording sets it to. The Imperials are completely undetectable. The scale, weight, dynamic impact and control are so good I'm unsure if I've ever heard better. Everything about this speaker sounds right; imaging is lucid, the music breathes and you physically feel each note, even when it's just a delicately soft piano stroke it still has a physical sensation. The most complex piano works played at live volumes hold together with grace and seem to have no flaws. On music that has a bodacious bass line it just thrills your spirit and achieves a power and authority that seem to be impossible from such small speakers. This is with everything set dead flat. The microphones are no longer EQ'ed, everything seems very forgiving, there are zero feedback problems, and we are still using a cheap \$200 Behringer mixer with some drum mics.

The old black Stereophile Test CD with the church organ track, something I've heard at least several hundred times over the past 15 years, came off so well that I was able to construct the mechanism in my mind that opened the air flow into each pipe of the organ, hearing how each puff affects the initial attack profile of the note. In other words, I had so much detail that I could easily understand exactly what and how the sound I heard was being created, as if it had been real.

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WHERE DOES THIS LEAVE US?

You are probably wondering what the hell changed so much between parts three and four, right? Two things; the room in fact got significantly better and the driver was changed from the original DFR8 to the shielded DFR8. The biggest difference was the driver with respect to the bass response, but the room helped to tip the frequency balance away from the top end. BTW, the listening room is not yet finished.

There will be much work ahead once I start measuring the room. And speaking of measuring things, I'm anxious to spend more time on the ZOB project, looking at the impedance and frequency response of the ZOB.



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In summary, the results have changed dramatically from part three, making this a product that will be viable for the DIY market and user friendly for those who order the speakers completely finished. The options are now to use them stand alone, stand alone with a sub, or stand alone with a crossoverless broadcast system.

The biggest thrill is that with this alternate shielded DFR8 the efficiency of the coupling between the driver and the chambers has increased sufficiently to make the speaker usable on its own for many people. Even though the efficiency of the shielded DFR8 is 2 dB less than that of the unshielded DFR8, it is not noticeable. In fact, it seems louder now than it did, and that's got to be because there is so much more low frequency content than before. This validates my original idea behind the design of the chamber now that it works more efficiently. In my eyes, that's one hell of a Zen speaker since frequencies below 100Hz are all passed to a driver that doesn't exist! There's just an empty chamber. How cool is that?

Not to mention the purity and phase coherency of the bass and if you add broadcast speakers, those characteristics remain the same. No powered subwoofer can achieve this seamless integration; with a line level input and active crossover, it's impossible. Interestingly enough, that means that no-one in the world has ever heard bass this clean, textured, pitch perfect and open from a moving coil speaker that is a true full range point source because nothing like this has ever existed, at least to my knowledge.

SUPERIOR APPROACH ?

To get a single eight inch driver with no crossover to create a full balance of usable bass down to 40Hz without equalization in such a narrow baffle has never been done either. It is the ultimate in coherency, supporting the ideal that for a speaker to accurately reproduce a kick drum accurately, it must be a point source able to reproduce the whole range of that drum, which is typically 40Hz out to 10kHz or more.

If you reproduce the drum any other way, the subtle differences in phase angle between the main driver and the second driver are enough to alter the pitch definition and smear the upper harmonics. The construction characteristics of the drum can be easily deduced and the type of heads used and tuning if you're standing in front of it. On a stereo, usually not but with this ZOB approach, it's no problem.

Also remember that this narrow baffle allows the speaker to disappear completely without becoming a large room reflector when compared with many other open baffle designs. As a result, it images exceedingly well.

If you opt for the crossoverless broadcast system, the source for the broadcast amp is a pair of live microphones which is a whole step better than live microphones recording music and reproducing it back by CD player. So signal quality is very high going to the broadcast system and the system itself is reproducing the actual in-air sound of the main driver you're listening to in the Open Baffle. The harmonics are matched and the magic begins.