Designing Speakers

Part 3 Bass Reflex

Continuing this series on designing your own speakers, Peter Comeau looks at the ups and downs of the bass reflex enclosure...

It won't have escaped most readers' notice that the majority of commercial speaker designs available on the market are vented boxes or what we call 'bass reflex' or 'ported' designs. This is our third class of enclosure and covers a multitude of concepts from bandpass to Transmission Lines, taking in a fair number of oddball ideas along the way.

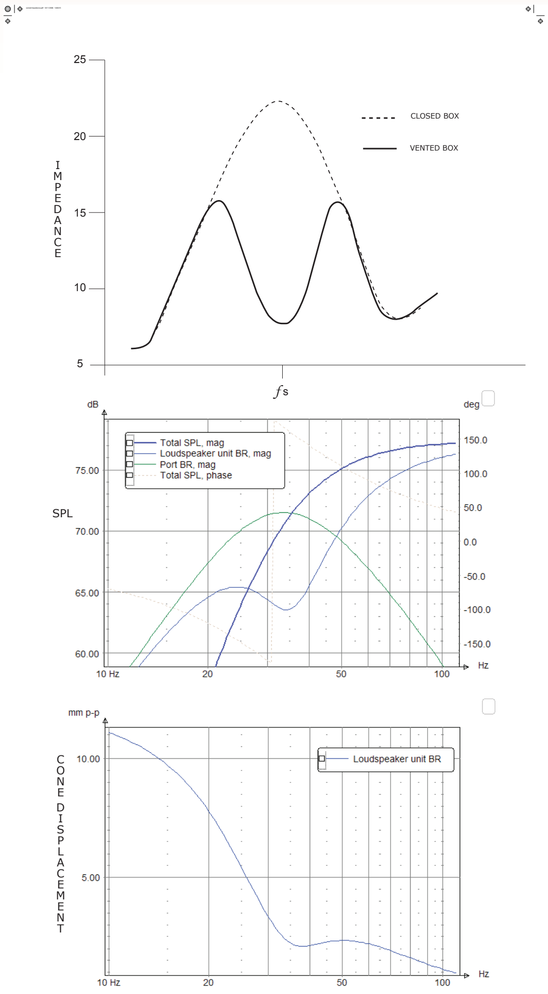
THE BASS REFLEX BOX

Let's deal with the positive aspects of the vented box first. Compared to the closed box the vented box has greater bass extension, superior power handling and lower distortion over the 'wanted' bandwidth, and a higher efficiency level. Sounds like it's got everything going for it!

A vented, or Bass Reflex, box achieves these aspects because it reinforces the output of the bass unit by acting as a Helmholtz Resonator. The technique relies on allowing the port output to increase as the bass unit output falls in level. This happens automatically but the performance of the design relies on how the 'crossover' between the bass unit output and port output is managed.

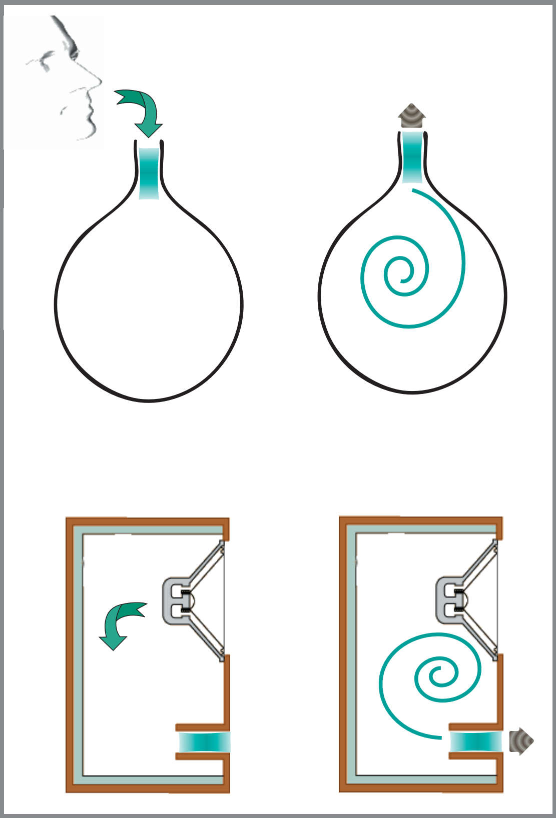
Actually we can 'see' how the well the efficiency of the system is working by looking at the drive unit impedance graph. If you compare this to the closed box system impedance last month you will see that instead of having one 'hump' that shows the resonant frequency of the system we now have two humps. Some viewers have thought that the twin humps of a reflex cabinet show two resonances. Actually there is still only one system resonance, the twin humps are because we are using the drive unit to measure the impedance.

What actually happens here then? It's probably easiest to imagine the system as a closed box with a 'port' that takes over from the bass unit as a provider of bass output at the system resonance. What the bass unit sees is therefore as follows. If you follow the trace from 100Hz downwards the bass unit impedance starts to rise towards the system resonance, just as it would in a closed box. But then as the Helmholtz resonance starts to tune towards its optimum point the port output starts to take over from the drive unit output – so we see this as a fall in drive unit impedance. At the system Helmholtz resonance point all the bass output is coming from the port and virtually none from the bass unit. So as the bass unit isn't



The top graph shows a large closed box system tuned to 34Hz (dotted) compared to a smaller bass reflex box with the same tuning. The graph shows the impedance of the drive unit which falls to a minimum at the system tuning frequency of the vented box.

As driver output falls the port output increases (middle graph) and the two combine to extend the bass response. Unfortunately driver cone excursion increases rapidly below the system tuning frequency (bottom graph).



A simple Helmholtz resonator is a bottle with a narrow neck. Blow across it and you push the mass of the air in the neck of the bottle in, whilst the springiness of the air in the bottle pops it out again setting up an oscillation. Substitute your breath for a drive unit and the bottle neck for a port and you have a bass reflex speaker.

HELMHOLTZ RESONANCE

A Helmholtz resonator is a cavity containing gas with an open hole or port in it. An empty wine bottle is a good example. Blow across the mouth (port) of the bottle and you push on the mass of air in the neck of the bottle. This pushes down against the air in the bottle which compresses and increases the pressure inside the bottle. As this pressure is now greater than atmospheric pressure the air pushes back on the mass of air in the neck forcing it partially out of the bottle. This reduces the air pressure inside and the mass of air is sucked back in, setting up the oscillation. As you continue to blow you keep pushing this mass of air back in again and so continue the oscillation, thus producing a continuous note.The frequency of oscillation is determined by the spring constant k divided by the mass m.

EMBED Equation 3. In our case the spring constant is the volume of air inside the enclosure; the smaller the volume the springier the air and the higher the frequency. The mass is the mass of air restricted in the port; make the port longer and the mass increases so the resonant frequency goes down.

moving at this point its impedance is at a minimum, hence the 'trough' in the graph. Moving lower in frequency the bass unit starts working again as the port output dies away so the impedance rises.

To cut a long story short, the 'trough' in the impedance graph marks the frequency of system resonance. If the crossover from drive unit to port is working at maximum efficiency then the system resonant 'trough' will bisect the drive unit impedance. We will see this as equal 'humps' either side of the trough.

If one of the humps is bigger and broader than the other then the system is mis-tuned. This needn't be a bad thing. In some cases it can be better if the system is de-tuned. There's a fair amount of freedom for the designer here, so let's look at the pluses and minuses.

BASS REFLEX TUNING

First of all a bass reflex system working at maximum efficiency can sometimes be heard as a 'one note bass'. We should never forget that reflex boxes are acoustic resonators. As with any resonance if the system is relatively undamped then the oscillation continues after the energising impulse has passed. We hear this as a stronger bass output at the resonant frequency than at other frequencies – it sounds like everything in the bass is centred around that one note.

So we can either add extra damping, or de-tune the system, or both. Why ever would we want to de-tune the system? Well, for example, we can change the balance of bass unit output to port output. By de-tuning the system the port output falls compared to that of the bass unit but, unlike damping which ostensibly achieves the same thing, the Q of the system is less affected.

A more rational reason is because of what happens to the bass unit below resonance. Bass unit output starts to rise below resonance and, unlike a closed box, there is no restoring force from air pressure inside the box as the box is now 'leaky' through the port. Bass unit cone excursion increases rapidly as the frequency falls.

This is undesirable. It not only leads to the 'cone flapping' seen when playing a slightly warped record through the system but also allows the voice coil to move out of its linear region. Once the bass unit is working at a non-linear point in its travel then everything gets distorted – upper bass, midrange, the lot!

There are two ways round this. One is to add damping to the system by filling the port with, say, straws or open cell foam to provide resistance to the airflow. The other is to de-tune the resonance well below the point of optimum efficiency. You get two bonuses with this, one is that the system resonance falls in frequency and is audibly less objectionable (on the basis that any resonance can be heard as such). The second is that cone displacement is less at frequencies within the audible bandwidth so that the bass unit is more likely to remain within its operational linearity. The downside, with both methods, is loss of efficiency but, as we pointed out last month, we can counter this in larger speakers with good bass extension by utilising room gain. All is not lost.

Next month: Bandpass enclosures and Transmission Lines