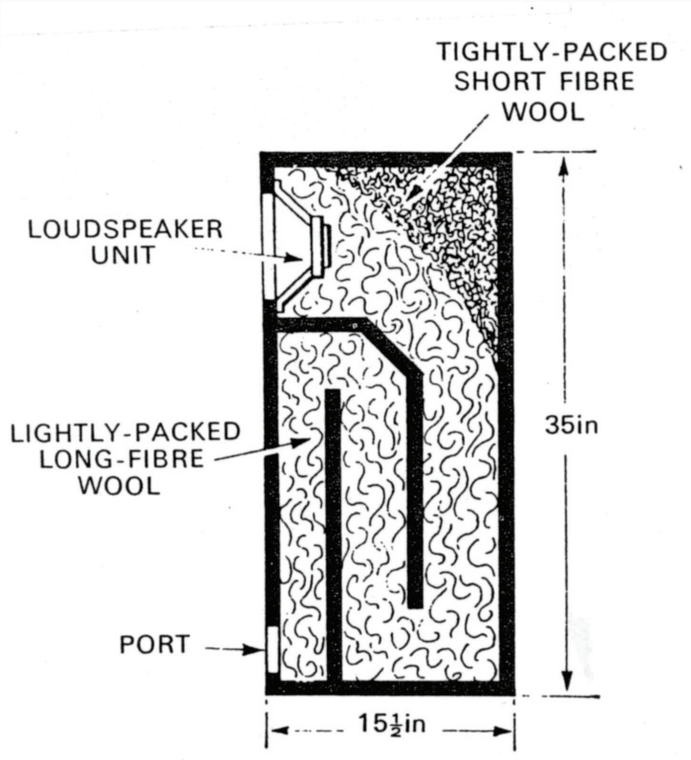
Designing Speakers

Part 4 Quarter Wave and Transmission Line systems

Transmission Lines are often considered the true enthusiast's speakers. Peter Comeau looks at



Last month we showed how the port of a bass reflex loudspeaker helps extend output at lower frequencies by exciting a Helmholtz resonance in the air volume of the cabinet. The mass of air in the port is, if you like, acting as a passive drive unit that augments the output of the main bass unit.

Now it doesn't take a leap of imagination to translate that mass of air in the port into a second passive drive unit. We call this a Passive Radiator (PR) or Auxiliary Bass Radiator (ABR). The PR can be as simple as a drive unit without a magnet and voice coil, in fact it is quite common to use the same cone and surround as the active bass unit. You can achieve better efficiency and extension by designing a PR specifically for the job, however, and there are several software programs that can help you do that.

Now that we have shown that the port or PR is behaving as a drive unit, albeit a passively driven one, why don't we make the port or PR the drive unit proper? This is what happens in a bandpass enclosure where the port or PR provides all the bass output from the system. Fig.1 shows a cutaway of a bandpass enclosure and its response.

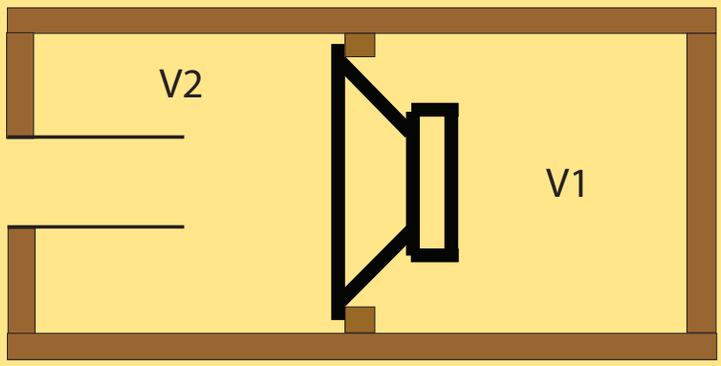
So we can use a bandpass enclosure to provide bass without the necessity of a crossover. There are downsides to its use in hi-fi, however. For a start the filter slopes approximate to 18dB/octave at each side, better than a vented box but worse than a closed box and, remember, you will need greater overall enclosure volume than an equivalent closed box system because of the added front enclosure. The front enclosure also contributes considerable ringing artefacts and pipe resonances outside the bandpass response, all of which are clearly audible, and can only be controlled using considerable amounts of enclosure damping which reduces system efficiency. The end result is that you don't often see bandpass enclosures used in high performance hi-fi systems.

THE QUARTER WAVE LINE

There is another, high efficiency, way of using a port in the box to provide bass output and that is the Quarter Wave Line. This type of enclosure utilises a pipe resonance to augment output. The principle is well known in musical instruments where a column of air in a tube is excited at one end with the output appearing at the open end of the tube (an organ pipe is probably the best example).

If we leave the line relatively undamped then the resonance, where the length of the line is a quarter of the wavelength, is easily excited and the output from the open end of the pipe is fairly prodigious. In addition the mass load on the driver at system resonance is such that the cone displacement is small for substantial overall output.

However, before we get too excited, the fundamental pipe resonance is not the only excitation. Harmonic modes occur at multiples of the pipe resonance, also at a very high level, and these extend right up into the midrange where they can prove extremely troublesome. Adding damping to the walls of the pipe can reduce the level, and hence audibility, of these modes but the efficiency of the system is also reduced. Similarly, as the most objectionable mode is the third harmonic, mounting the driver up to a third of the way down the line from the closed end will



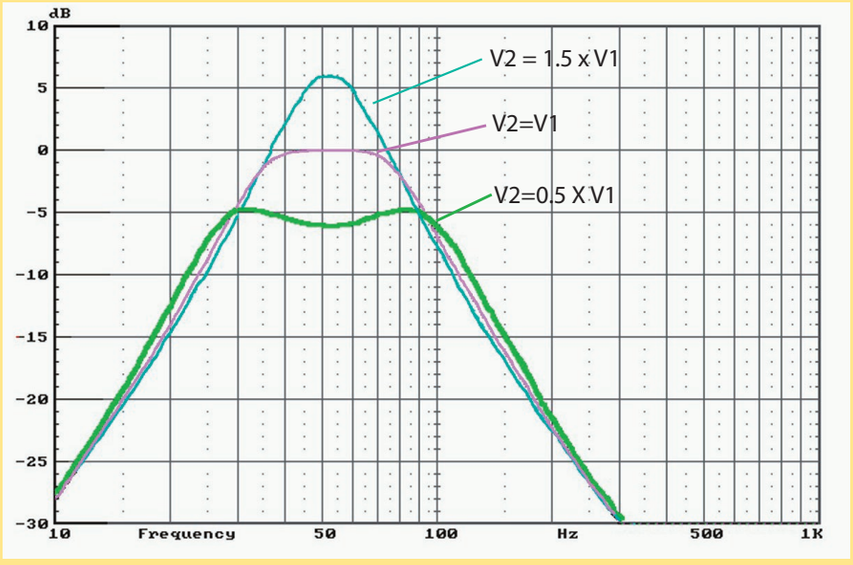


Fig.1 bandpass.pdf

A BandPass enclosure is a special type of bass reflex where the active drive unit is loaded by an air volume at the rear and front. The rear volume can be a closed box or a vented box (Bose have a patent on the latter principle) whilst the port in front of the drive unit provides the main output.

You can see that the port acts as a filter in front of the active drive unit and has the typical bass reflex performance with a system resonance positioned higher in frequency (blue curve). By judicious juggling of the port area and length, enclosure volume and drive unit characteristics we can flatten the main peak to provide a broader 'bandpass' output (green and purple curves).

avoid undue excitation at higher frequencies.

One variation on the quarter wave line, which made its way into commercial designs from Castle, is to 'tune' the open end of the pipe by restricting its radiating area. Various DIY methods actually use a port tube but Castle's method was more ingenious. By mounting the open end of the pipe slightly above a plinth the radiating area became the gap between the plinth and column walls, and the gap could be 'tuned' to lower the Q of the LF output.

One aspect to bear in mind with quarter wave loading is the length of line required for a truly extended bass response. The wavelength at 30Hz, for example, is 12m requiring a 3m line for efficient output at this frequency – a rather large cabinet ensues! A more common use for shorter length quarter wave designs is to bolster the bass output below 100Hz from full range drivers which typically have weak bass performance and therefore need all the help they can get.

TRANSMISSION LINE SYSTEMS

The consideration of line length, and therefore large speaker size, brings us neatly on to the Damped Line system more commonly known as the Transmission Line speaker. TL speakers are a cross between a reflex and a quarter wave pipe. At first this seems an odd combination, neither one nor the other might appear to be a bit of a bodge. And it's true that the 'science' of TL speakers is not at all exact. Only by constructing and experimenting with a TL can you begin to get reasonable results – doing things 'by the book' doesn't often work anywhere near as well as expected.

The concept behind the true transmission line is founded on the principle that the output of the drive unit is completely absorbed, down to all except the lowest frequencies, throughout the length of the line. This concept has rarely been put into practice – the B&W Nautilus being just about the only commercial

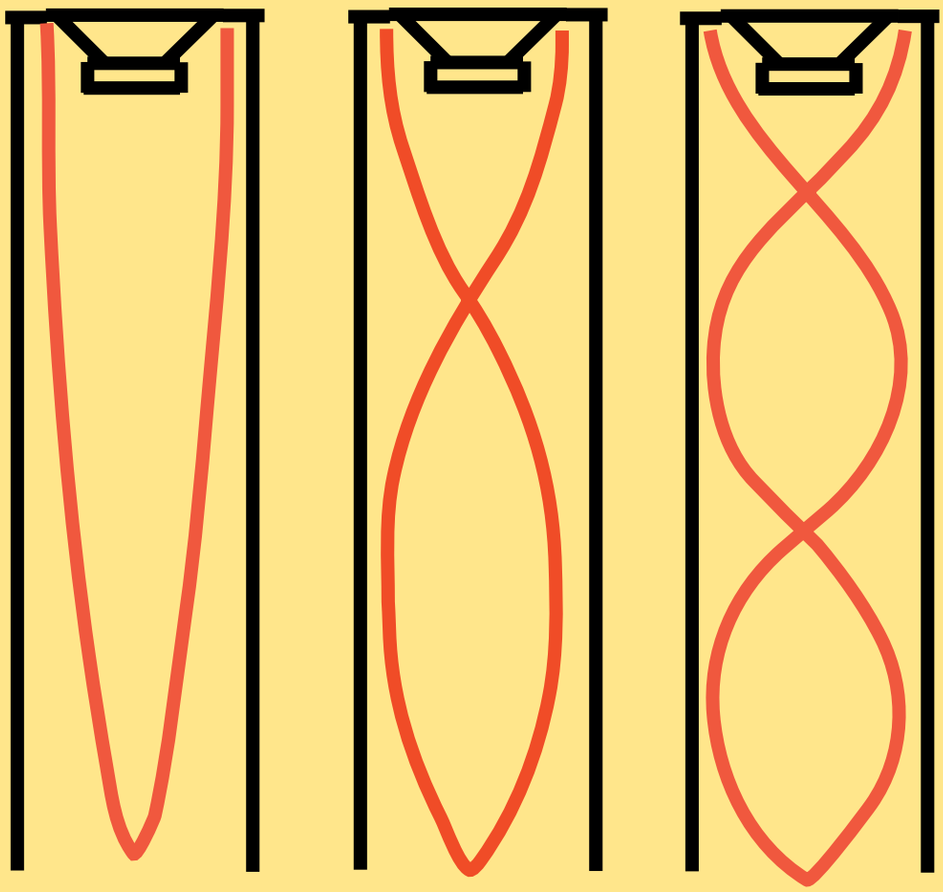


Fig.2 pipe_harmonics.pdf

Both the quarter wave line and TL systems are based on the resonance that occurs in a pipe that has one open end. The column of air in the pipe is easily excited at a frequency where the line is one quarter of the wavelength. Unfortunately harmonics of the fundamental resonance continue to midrange frequencies and require damping to avoid horrendous colorations.

example extant. Most so-called TL speakers work around the main problem of the 'transmission line' – that the line can only absorb frequencies down to the frequency where the length of the line equals the half wavelength – by opening the end of the line through a 'port'.

Once you open the line through a port then the theory changes completely. What you end up with is the same as a column open at one end and driven at the other – in other words a quarter wave pipe. The pipe resonance can be 'tuned' by choosing a length and port opening area that puts the fundamental resonance of the line close to the free air resonance of the drive unit. This enables the drive unit to develop considerable power down to its fundamental resonance resulting in the considerable extended bass 'rumble' that big TL speakers commonly exhibit.

Unfortunately you don't get something for nothing. If the line is left relatively undamped then, just as in the quarter wave pipe, associated modes occur at higher frequencies, usually multiples of the fundamental. These pipe resonances are clearly audible as a boom in the bass and a honk in the midrange. To overcome these modes damping is added throughout the length of the pipe. Naturally such damping reduces the efficiency of the quarter wave resonance, so to prevent lower bass from being damped to insignificance the line is often treated either by lining the walls of the pipe with foam or felt or using an open fibre form of filling such as long hair wool.

With optimum damping applied to remove all the upper pipe modes, the typical sound of a TL speaker exhibits a gradual loss in bass power as the frequency decreases until one reaches the area of the fundamental resonance when power in the room becomes significantly audible. Fans of TL speakers describe this as 'hearing bass only when it is really present'. By that they mean that the resonant boom of the typical bass reflex is missing and, instead, only programme material with considerable low bass content generates satisfying bass power.

But there are ways round this. For example tapering the line and placing the bass unit part way down the line, as well as letting the bass unit drive the line from an upper enclosure, can reduce many of the objectionable resonances without excessive damping and thus yield a bass performance which is more naturally balanced and revealing. We will explore this further when we work on our practical TL project later in the series.

Next month: Horns and Efficiency