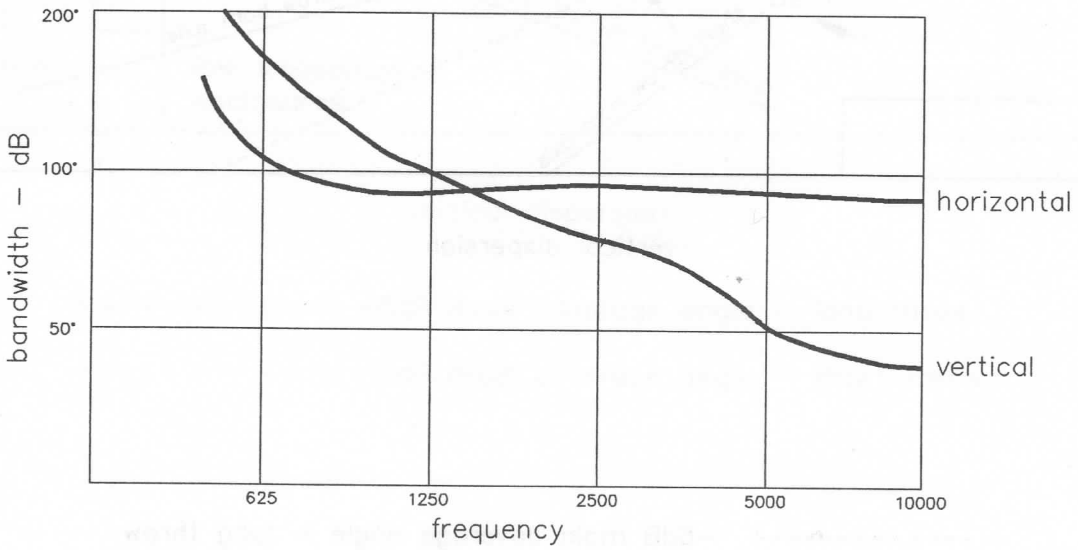
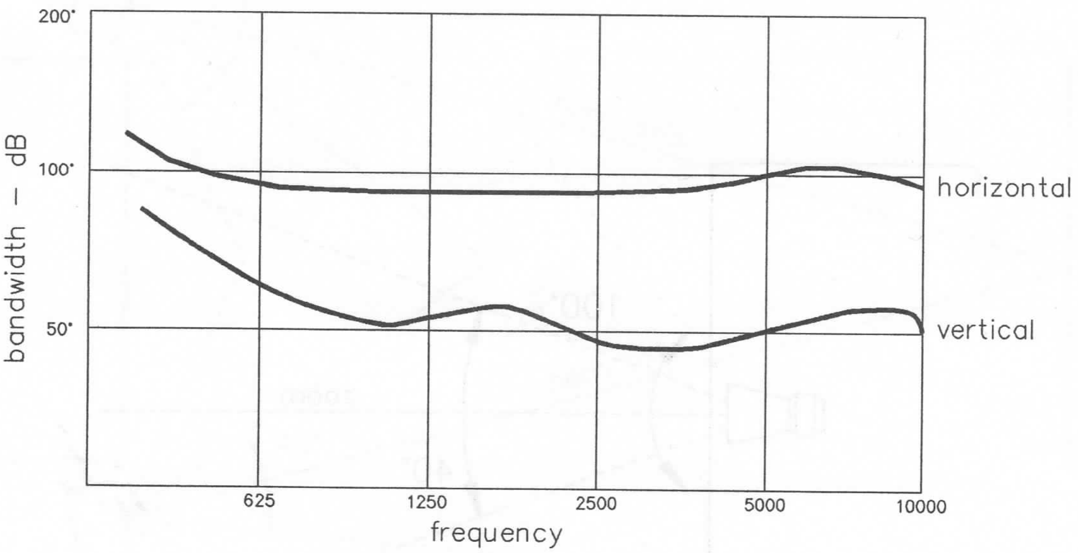
Thus it can be seen that directing mid-range and high frequency horns enable proper control of coverage patterns. By using manufacturers' horn specifications, selection can be made to avoid excessive overlap and eliminate interference and lobing caused when two horns are serving the same area.



Beamwidth characteristics for a 90 degree x 40 degree radial horn.

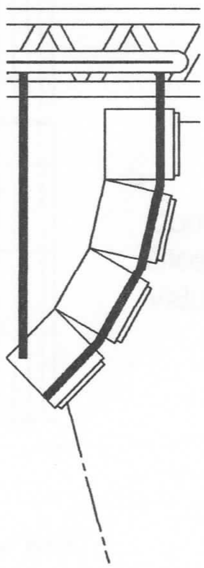


Beamwidth characteristics for a 90 degree x 40 degree C.D. horn.

These notes, whilst not getting deeply into theory and mathematics, will enable a better understanding of manufacturers' specifications and the application of broad and narrow band devices to achieve constant and uniform coverage of the audience area.

At the other end of the scale, ie. the large concert P.A. system, the best results are obtained with clusters operating from 125 - 150 Hz up with the sub-bass system on the floor.

The clusters are curved on both the horizontal and vertical planes.



This is achieved using trapezoidal shaped cabinets. These are either full-range modules or a combination of different mid-range high frequency enclosures, to achieve the required 'foot print' of constant pressure over the target audience area.

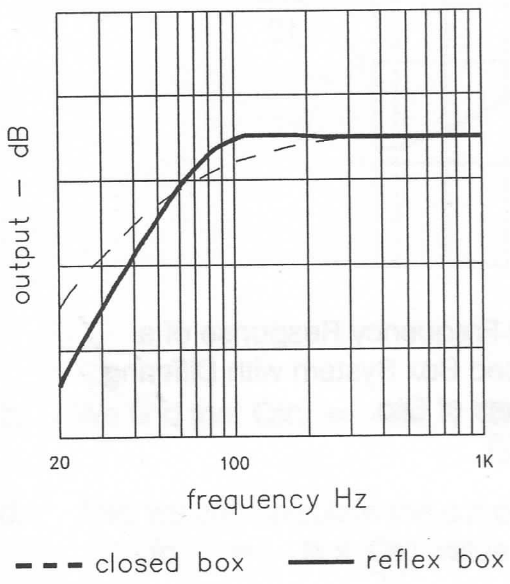
1.4.1 Closed Box Low Frequency Systems

A totally closed or sealed enclosure is the most basic design available to the amateur enthusiast in terms of ease of construction. However, this simplistic design can provide excellent results and should not be ruled out.

The advent of the compact high power cabinet has seen a decrease in the use of the sealed enclosure, as bass reflex designs can be physically smaller and therefore more commercially viable. Sealed enclosures have been restricted to use in domestic Hi-Fi loudspeakers by utilising the conventional air suspension principle which is not suitable for high level sound outputs.

High tech digitised audio reproduction systems offer increased dynamic range and band-width, and as result impose greater loads on loudspeaker cones, particularly the excursion. This offers an ideal opportunity to utilise the equalised closed box design where physical size is not a limiting factor.

For high power applications sealed loudspeaker enclosures have to be big, and when optimised provide the maximum damping effect on the rear of the loudspeaker cone, thus providing the desired characteristics of ultimate displacement, limited power handling capacity, and excellent transient capabilities. The low frequency roll-off is shallow when compared with other bass systems, ie. at 12 dB/octave, a closed box with the same fc as a reflex box will have greater low bass output as well as improved transient stability. This property makes the design suitable for electronic applications or equalisation if there is sufficient amplifier headroom.



Comparison of Relative Outputs for a Closed and a Reflex Box of Equivalent Values

For the applications we require, the compliance or stiffness of the air within the enclosure is much greater than the compliance of the loudspeaker. The objective of the design is to align the Q of the system (Qtc). The Q in mathematical terms is the ratio of reactance to resistance and therefore can be used to define the resonant magnification in loudspeakers. It represents the total interaction between the Electrical (Qes), Mechanical (Qms) and the Enclosure (Qtc) to control the final resonance and response of the system. The subjective qualities of various values of Qtc can be summarised as follows -

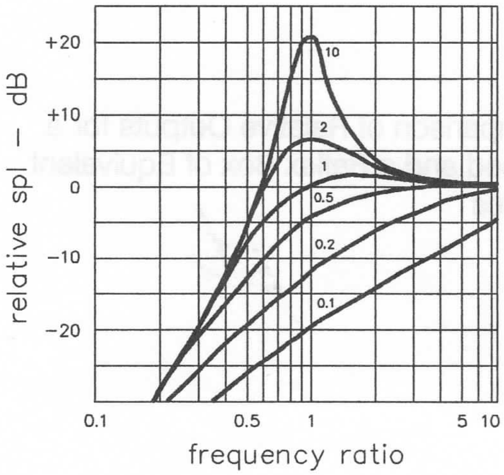
Qtc = 0.5
This is the critically damped response with perfect transient performance, but it is usually regarded as being too 'tight', and overdamped, but it is of course ideal for equalisation.

Qtc = 0.7
This provides the alignment with the maximum flat response before roll-off designated B2 Butterworth alignment.

Qtc = 1.1
This provides the alignment with the maximum power handling and efficiency although transient response is slightly downgraded.

Qtc = 1.2 +
These values equate to a 'boomy' and are generally regarded as undesirable. Therefore the Qtc should be selected between 0.5 and 1.0 for best results.

Bass drivers for use in these enclosures should have a relatively high cone mass, low resonance (cloth edge only) and moderately large magnets, their Qtc being around 0.3.



Low Frequency Response of a Closed Box System with Differing Values of Qtc.

By using Qt and Vas for the particular loudspeaker, the Q of the system can be calculated for given enclosure sizes until the ideal performance and practical size is found.

Using:

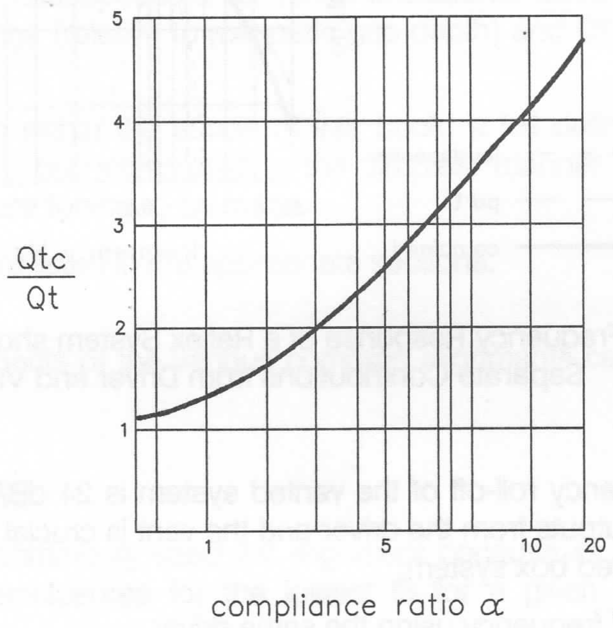
Vb	=	Enclosure Volume (chosen) in litres
Vas	=	Compliance Equivalent Volume for Loudspeaker in litres
Qts	=	Total Q for Loudspeaker
Qtc	=	Total Q of System (Loudspeaker and Enclosure)
fc	=	Frequency of Cut-off (-3dB)
fs	=	Resonant Frequency of Loudspeaker

a. We can find the compliance ratio α

$$\alpha = \frac{Vas}{Vb}$$

(Note that units of measure for each must be the same).

b. From the graph, we can determine the value of $\frac{Qtc}{Qt}$



c. We find that $Qtc = Qts \times \frac{Qtc}{Qt}$

d. Also we can calculate the cut-off frequency

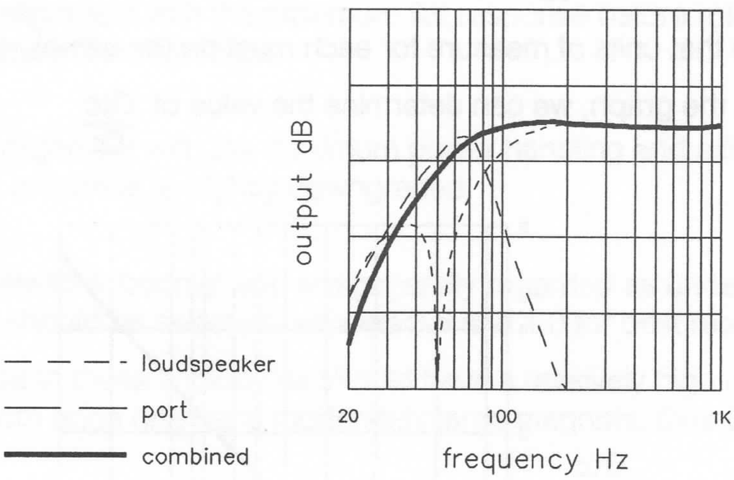
$$fc = fs \times \frac{Qtc}{Qt} \text{ value}$$

Note that for two loudspeakers in a single enclosure, fs and Qts will be the same as for a single loudspeaker, but Vas used in calculations will be twice that of the single unit.

1.4.2 Vented Box Low Frequency Systems

The idea of venting or porting an enclosure to assist its low frequency response using the Helmholtz principle is rather an old concept, the first designs being used over sixty years ago. Many individuals over the years have made a great contribution to defining and refining the mathematical analysis, culminating in the definitive works by Thiele and Small. These have led to the reflex design gaining favour over the closed box design, particularly with the demands for compact mobile systems by today's audio reproduction requirements.

The total acoustic output from a vented enclosure is the sum of the outputs from both the drive unit and the vent, the output from the vent having a bandpass characteristic.

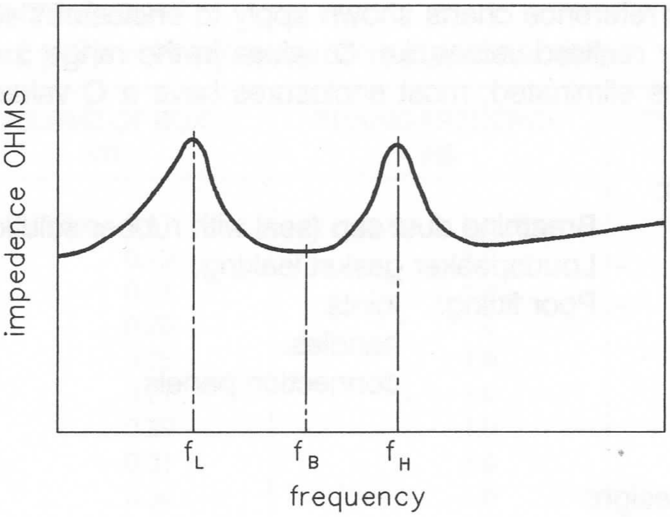


Frequency Response of a Reflex System showing Separate Contributions from Driver and Vent

The low frequency roll-off of the vented system is 24 dB/octave and so careful matching of the outputs from the driver and the vent is crucial to the main objectives gained over a sealed box system:

1. Lower cut-off frequency using the same driver.
2. Smaller box volume required for the same performance, which is the main reason for its great commercial success as a compact system.
3. Low cone excursion near the enclosure resonant frequency.

Incorrect alignment is most usually a poorly damped upper resonant peak, resulting in a boomy system on an over-damped lower resonant peak resulting in poor bass extension.



The matching of the various parameters to achieve an acceptable result is defined as an 'alignment', and unlike the closed box where Q is selected and subject to less variables, all vented box alignments by definition achieve a more or less flat frequency response with the variables aligned for optimum controlled low frequency response. Loudspeakers for reflex enclosures usually have low cone mass, short coil windings (relative to magnetic gap depth) and Qt's in the range 0.2 to 0.5.

In order to remain within the scope of this book, a full definition of the reflex principles is not given, but interpreted in the simplest manner possible to allow accurate reflex enclosure tuning to be made.

Technical works are listed in the appropriate sections.

The subjective aspects of the various common alignments can be summarised as follows:

Quasi Third Order - QB3

This is the most commonly used flat alignment because its low Q alignments require the smallest enclosures for the lowest f3 for a given driver. Transient response is good.

Super Fourth Order - SBB4

This flat alignment is characterised by low tuning and a good transient response, giving the optimum alignments for high Q loudspeakers.

Chebychev - C4

This non-flat equal ripple alignment is amongst the best, having a good low frequency extension.

The alignment reference charts shown apply to enclosures with losses that fall within the normally realised values, i.e. Q values in the range 5 - 10. Provided all potential leakage is eliminated, most enclosures have a Q value of approximately 7.5.

Causes of leakage:

- Breathing dust cap (seal with rubber solution).
- Loudspeaker gasket leaking.
- Poor fitting: joints.
  handles.
  connection panels.

To proceed with design:

1. Obtain driver Thiele and Small specifications, ie.
   - Resonance of loudspeaker - fs
   - Total Q of loudspeaker - Qts
   - Volume of air heving the same compliance as driver suspension - Vas
2. Study the alignment lists.
   Select an alignment that for the given Qts has the preferred box size VB and /or cut-off frequency f3.
3. Refer to porting chart using the tuning frequency fB to determine port diameter and length.
4. Cross check with minimum diameter chart.
5. Determine shape/number of ports and ducting.

SBB4 ALIGNMENTS CHART
Frequency of box (FB) = Frequency of loudspeaker (fs)

QTS	VOLUME OF BOX VB		TUNING FREQENCY FB		CUT-OFF FREQUENCY AT -3dB = f3	
0.20	= VAS x	0.17	= fs x	1.0	= fs x	3.37
0.21		0.19		1.0		3.15
0.22		0.21		1.0		2.95
0.23		0.23		1.0		2.77
0.24		0.25		1.0		2.60
0.25		0.27		1.0		2.47
0.26		0.29		1.0		2.29
0.27		0.31		1.0		2.15
0.28		0.34		1.0		2.02
0.29		0.37		1.0		1.90
0.30		0.39		1.0		1.80
0.31		0.42		1.0		1.70
0.32		0.45		1.0		1.60
0.33		0.48		1.0		1.51
0.34		0.51		1.0		1.44
0.35		0.54		1.0		1.37
0.36		0.57		1.0		1.31
0.37		0.61		1.0		1.26
0.38		0.64		1.0		1.21
0.39		0.68		1.0		1.17
0.40		0.72		1.0		1.13
0.41		0.76		1.0		1.00
0.42		0.80		1.0		1.07
0.43		0.84		1.0		1.04
0.44		0.88		1.0		1.02
0.45		0.92		1.0		0.99
0.46		0.97		1.0		0.97
0.47		1.01		1.0		0.96
0.48		1.06		1.0		0.94
0.49		1.11		1.0		0.93
0.50		1.16		1.0		0.91
0.51		1.21		1.0		0.90
0.52		1.26		1.0		0.89
0.53		1.31		1.0		0.88
0.54		1.37		1.0		0.87
0.55		1.42		1.0		0.86
0.56		1.48		1.0		0.85
0.57		1.54		1.0		0.845
0.58		1.60		1.0		0.84
0.59		1.66		1.0		0.83
0.60		1.72		1.0		0.825
0.61		1.78		1.0		0.82
0.62		1.85		1.0		0.81

QB3 ALIGNMENTS CHART

QTS	VOLUME OF BOX VB		TUNING FREQENCY FB		CUT-OFF FREQUENCY AT -3dB = f3	
0.12	= VAS x	0.042	= fs x	3.20	= fs x	4.33
0.13		0.050		2.96		3.99
0.14		0.058		2.75		3.69
0.15		0.068		2.57		3.44
0.16		0.078		2.41		3.21
0.17		0.089		2.27		3.01
0.18		0.10		2.15		2.83
0.19		0.110		2.04		2.67
0.20		0.130		1.94		2.53
0.21		0.144		1.85		2.40
0.22		0.160		1.77		2.27
0.23		0.178		1.70		2.16
0.24		0.197		1.63		2.06
0.25		0.218		1.56		1.97
0.26		0.240		1.50		1.88
0.27		0.265		1.45		1.79
0.28		0.291		1.40		1.72
0.29		0.320		1.36		1.64
0.30		0.351		1.31		1.57
0.31		0.385		1.27		1.51
0.32		0.422		1.24		1.44
0.33		0.463		1.20		1.38
0.34		0.507		1.17		1.32
0.35		0.557		1.14		1.27
0.36		0.611		1.11		1.22
0.37		0.671		1.08		1.16
0.38		0.738		1.06		1.11
0.39		0.813		1.03		1.07
0.40		0.897		1.01		1.02
0.41		0.994		0.99		0.98
0.42		1.10		0.97		0.94
0.43		1.23		0.95		0.90
0.44		1.38		0.93		0.86
0.45		1.55		0.91		0.83
0.46		1.76		0.90		0.80
0.47		2.01		0.88		0.77
0.48		2.33		0.86		0.75
0.49		2.73		0.85		0.73
0.50		3.26		0.84		0.71
0.51		3.99		0.82		0.70
0.52		5.07		0.81		0.68
0.53		6.8		0.80		0.66
0.54		18.5		0.79		0.65

C4 ALIGNMENTS CHART

QTS	VOLUME OF BOX VB	TUNING FREQENCY FB	CUT-OFF FREQUENCY AT -3dB = f3
0.25	= VAS x 0.25	= fs x 1.030	= fs x 2.40
0.26	0.27	1.050	2.23
0.27	0 .29	1.070	2.08
0.28	0.31	1.080	1.94
0.29	0.33	1.090	1.82
0.30	0.355	1.103	1.71
0.31	0.38	1.107	1.61
0.32	0.42	1.109	1.52
0.33	0.45	1.106	1.44
0.34	0.50	1.101	1.37
0.35	0.55	1.092	1.30
0.36	0.60	1.081	1.23
0.37	0.66	1.067	1.17
0.38	0.73	1.050	1.12
0.39	0.81	1.031	1.07
0.40	0.89	1.010	1.02
0.41	0.99	0.989	0.98
0.42	1.10	0.966	0.94
0.43	1.21	0.944	0.90
0.44	1.32	0.921	0.87
0.45	1.45	0.900	0.83
0.46	1.58	0.878	0.81
0.47	1.72	0.858	0.78
0.48	1.86	0.840	0.76
0.49	2.00	0.820	0.73
0.50	2.15	0.803	0.71
0.51	2.30	0.787	0.70
0.52	2.45	0.772	0.68
0.53	2.60	0.758	0.66
0.54	2.75	0.744	0.65
0.55	2.89	0.732	0.64
0.56	3.05	0.720	0.63
0.57	3.19	0.710	0.62
0.58	3.34	0.700	0.61
0.59	3.49	0.690	0.60
0.60	3.64	0.680	0.59
0.61	3.78	0.672	0.58
0.62	3.93	0.664	0.57
0.63	4.08	0.656	0.56
0.64	4.23	0.649	0.56
0.65	4.38	0.642	0.55
0.66	4.52	0.635	0.55
0.67	4.68	0.629	0.54
0.68	4.83	0.623	0.53
0.69	5.00	0.612	0.53
0.70	5.13	0.611	0.52