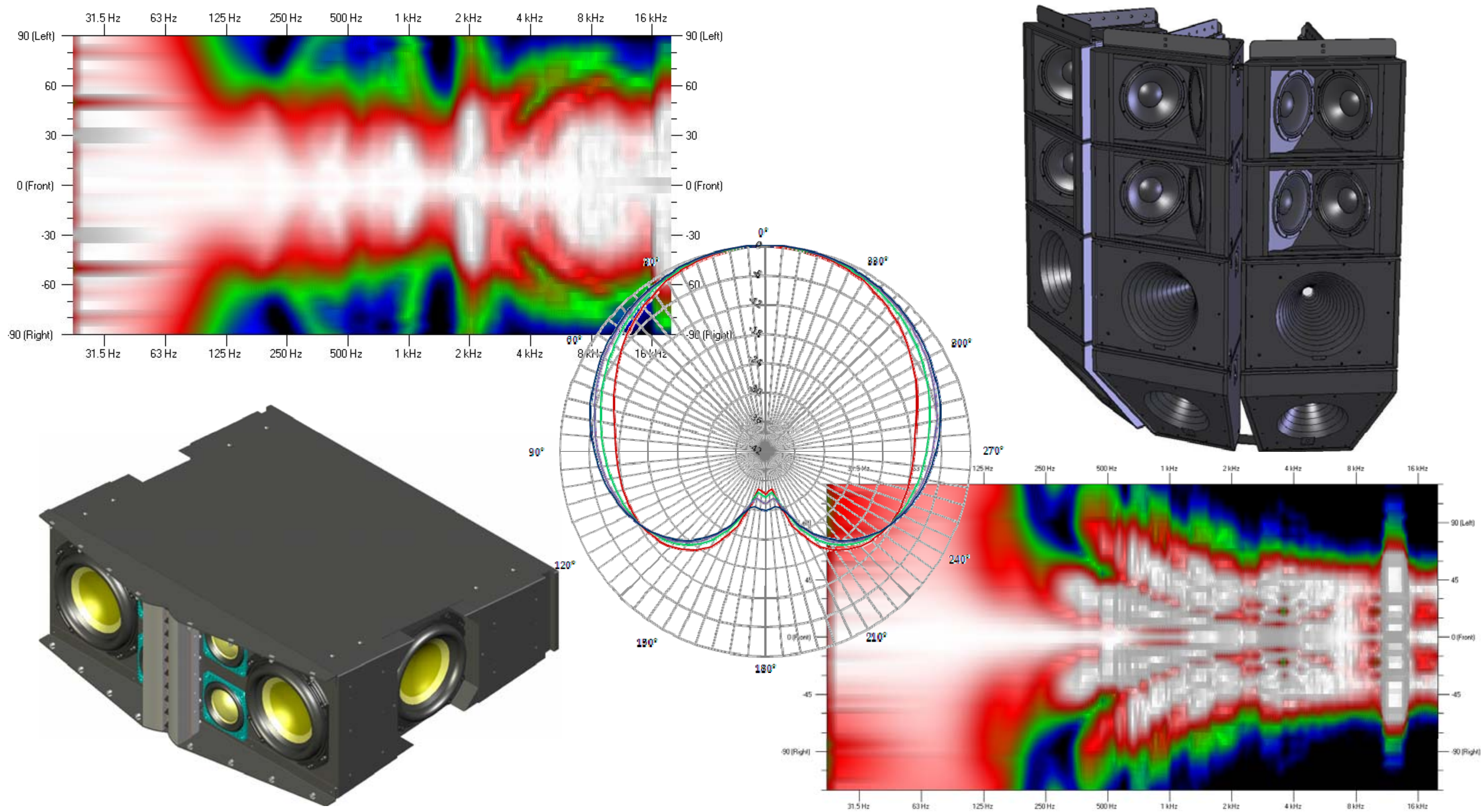
Audio System Coverage & Loudspeaker Design



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Measuring a Loudspeaker

Measurements used to determine the performance of a loudspeaker system and its individual components

1) Polar response and/or complete directivity balloons
2) On-axis frequency response (sensitivity)
3) Maximum continuous output SPL
4) Maximum peak output SPL

We measure the ***direct field*** of a loudspeaker or the components for design work at the loudspeaker level. As a loudspeaker designer this is the only thing within one's control.

We use techniques (anechoic chamber, windowing, gating, TDS, etc.) to eliminate reflections from the room in which we are measuring to get only the direct field.

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Requirements for a Good Loudspeaker

Consistent response over the intended coverage area

1) Constant Directivity – a well behaved loudspeaker

a) The directional characteristics of the loudspeaker should be the same over the entire operating bandwidth of the loudspeaker or to as low and as high of a frequency as possible.

b) Changes in the loudspeaker's directivity should occur gradually, not abruptly, and be consistent (either increasing or decreasing).

c) If the directivity response changes are inconsistent, the bandwidth over which they occur should be minimized.

2) Relatively Flat On-Axis Frequency Response

Requirements for a Good Loudspeaker

The desired directivity response of the loudspeaker must be a design consideration.

The components used and their relative placement (geometry) must be chosen carefully to yield the desired directivity response from the loudspeaker system.

Neglecting to do this often results in less than desirable performance.

Designing a Good Loudspeaker

In choosing the components (drivers & horns) for our loudspeaker, we must make sure they have the desired directivity within their individual pass bands ***and*** that they can yield the desired directivity through the crossver region when combined with adjacent pass bands.

These components must also have acceptably flat frequency response and be able to produce sufficient SPL in their individual pass bands so that the loudspeaker system can generate the desired/required SPL.

The finished loudspeaker must work well when used with other loudspeakers in a completed sound system.

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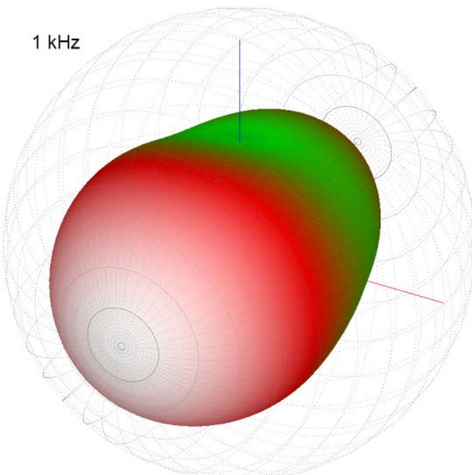
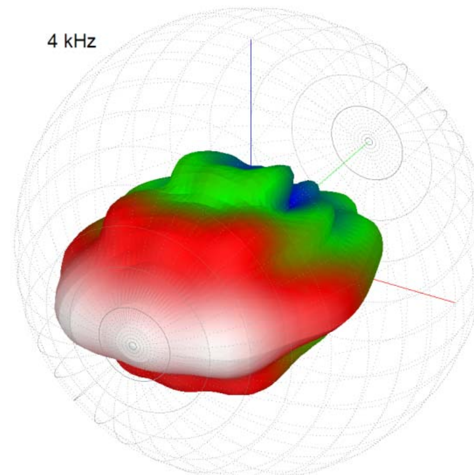
Designing For Directivity

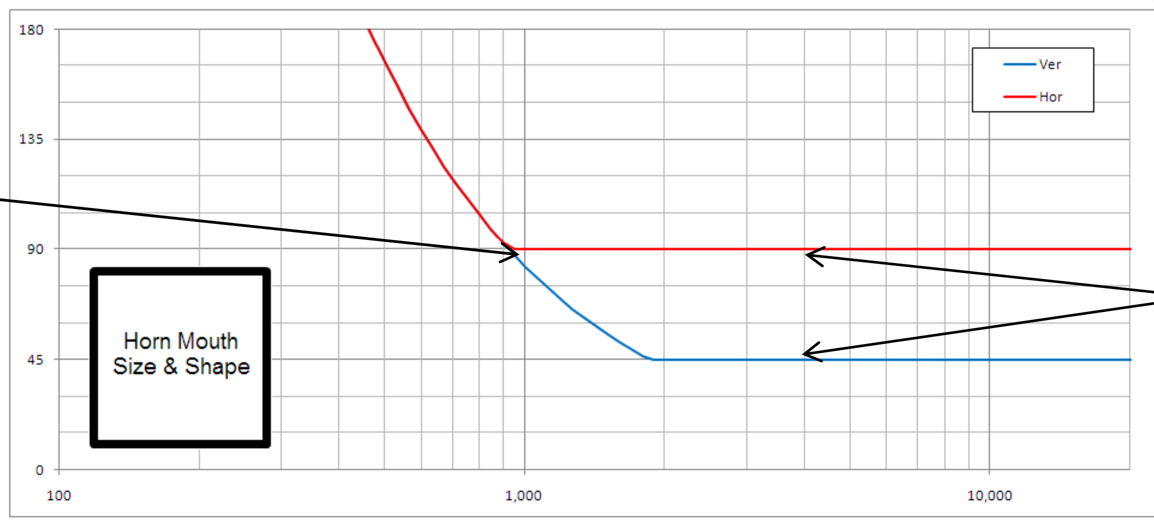
Horns can be a good way to gain directivity control.



Beamwidth graph and directivity balloons for a 90° x 45° horn with a 12 x 12 inch (30 x 30 cm) mouth.



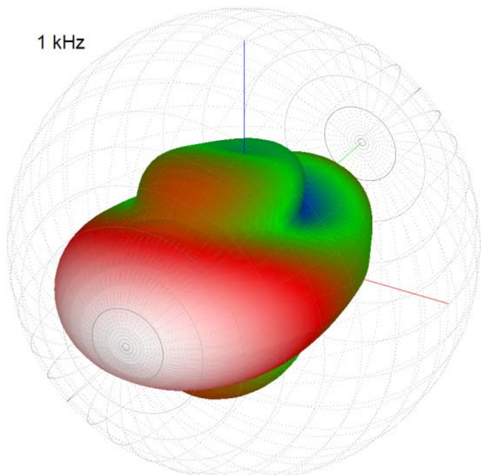
At 1 kHz the coverage pattern is approximately 90° x 90°



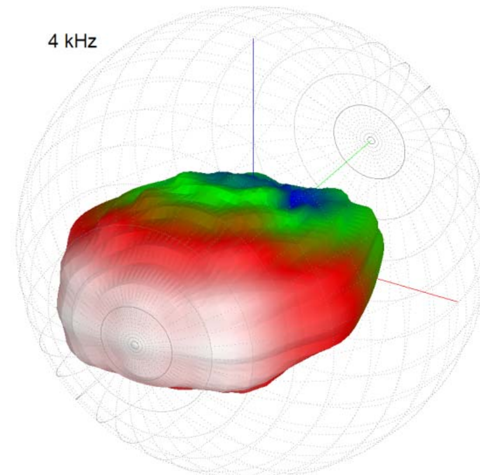
At 4 kHz the coverage pattern is 90° x 45°

Designing For Directivity

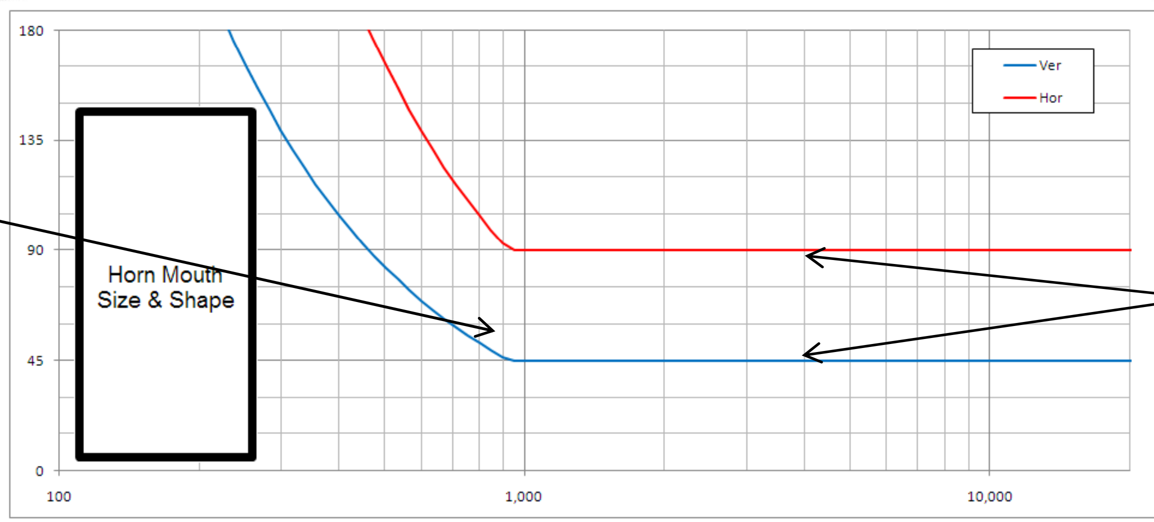
Physics dictates that larger devices are required for narrower coverage angles at lower frequencies.



Beamwidth graph and directivity balloons for a 90° x 45° horn with a 12 x 24 inch (30 x 60 cm) mouth.



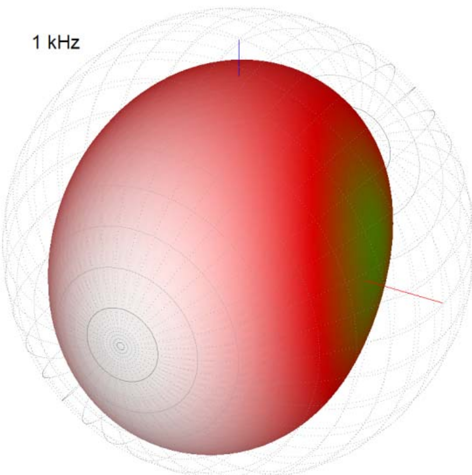
At 1 kHz the coverage pattern is still 90° x 45°



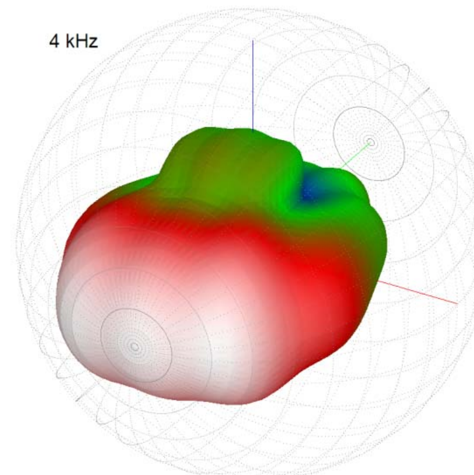
At 4 kHz the coverage pattern is 90° x 45°

Designing For Directivity

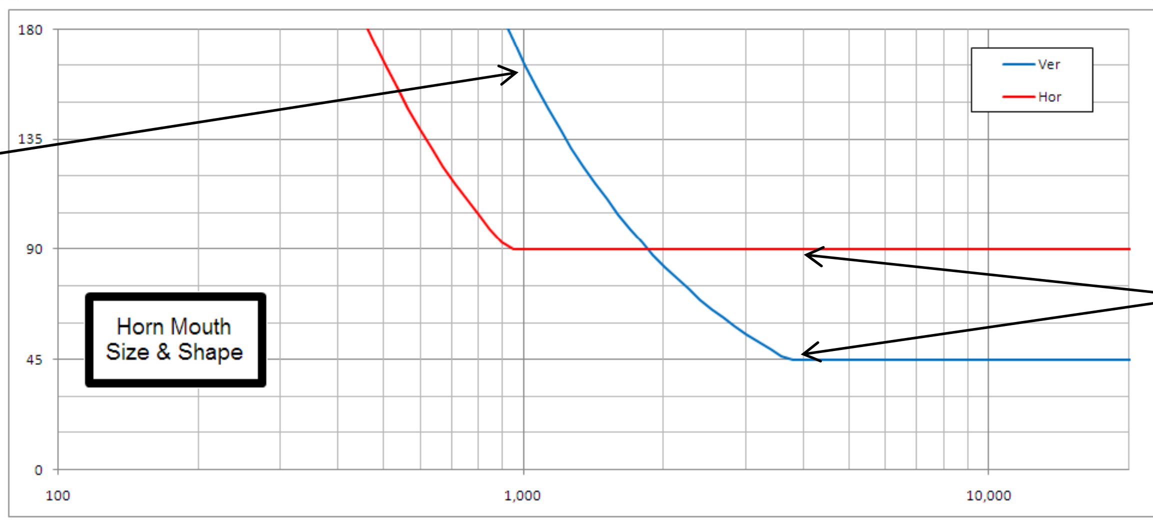
A horn with a small mouth dimension and a narrow coverage angle will lose directivity control at a higher frequency. This leads to ***Pattern Flip***.



Beamwidth graph and directivity balloons for a 90° x 45° horn with a 12 x 6 inch (30 x 15 cm) mouth.



At 1 kHz the coverage pattern is approximately 90° x 160°



At 4 kHz the coverage pattern is 90° x 45°

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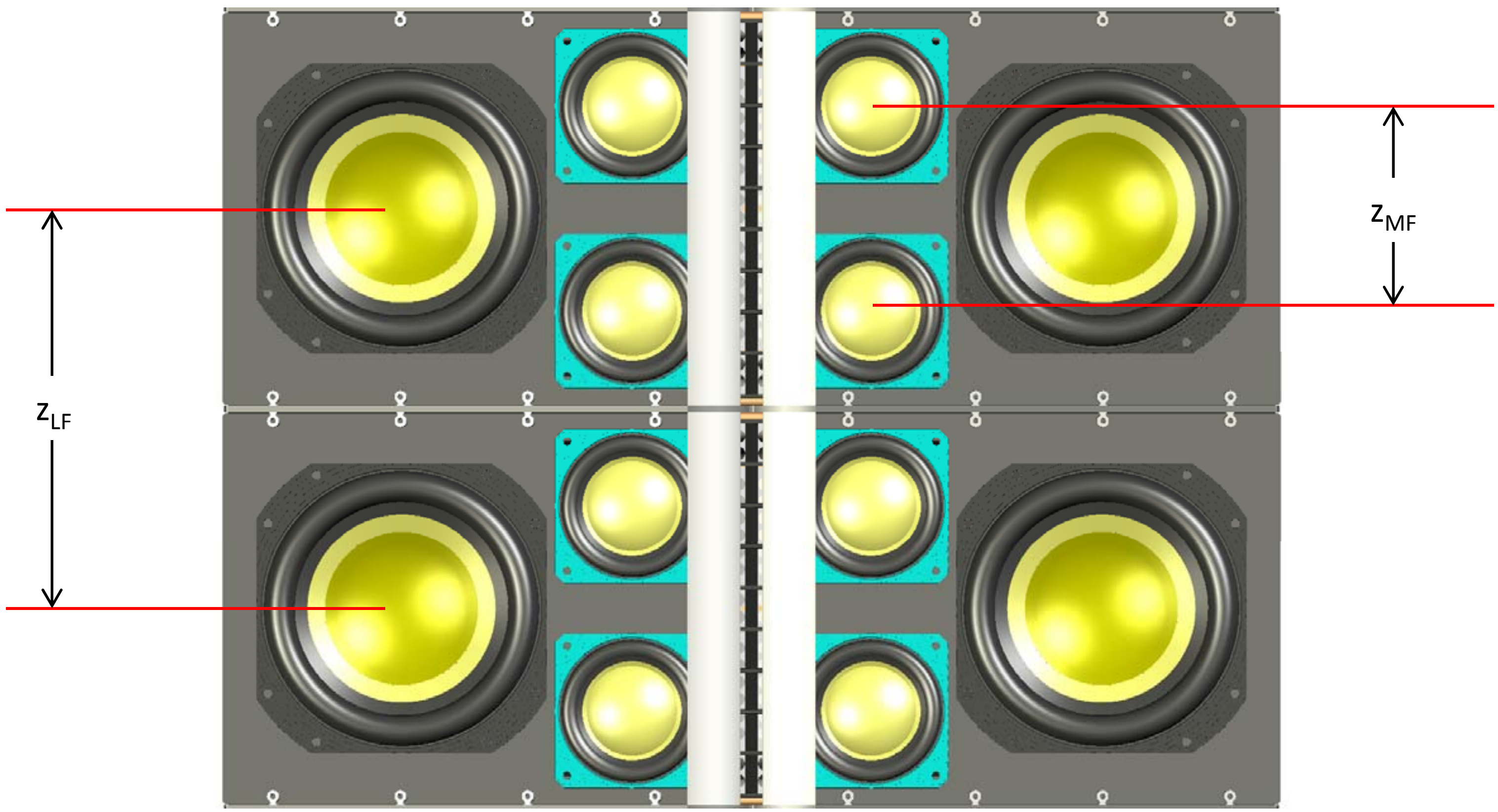
Designing For Directivity

Example driver geometry of a line array loudspeaker for good vertical directivity control.

Spacing should be no greater than 1/2 wavelength at highest frequency of operation (just above the crossover frequency) to minimize lobing.



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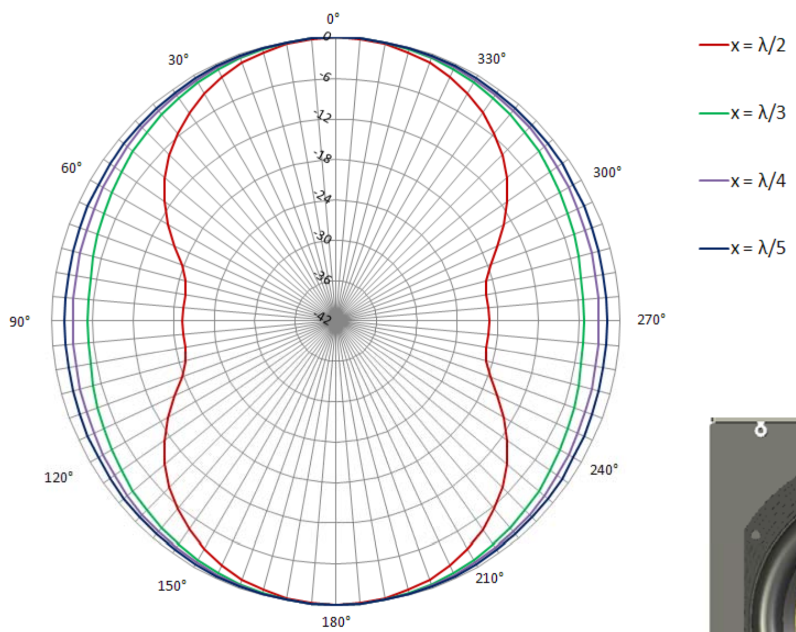
Designing For Directivity

Example driver geometry of a line array loudspeaker for good horizontal directivity control.

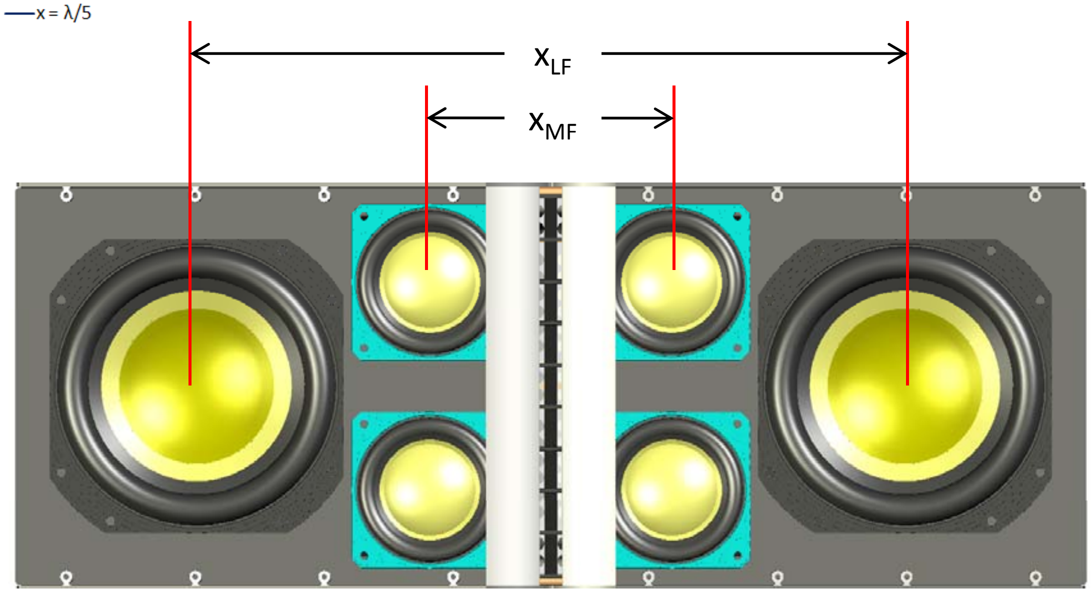
Spacing can be chosen to yield the desired directivity across a selected frequency range.



x = 0.5m (20 in.)

λ/2 = 340 Hz λ/3 = 225 Hz
λ/4 = 170 Hz λ/5 = 135 Hz

Choose crossover filters so that the HF narrowing of the woofers helps to narrow the broad LF response of the midrange drivers.



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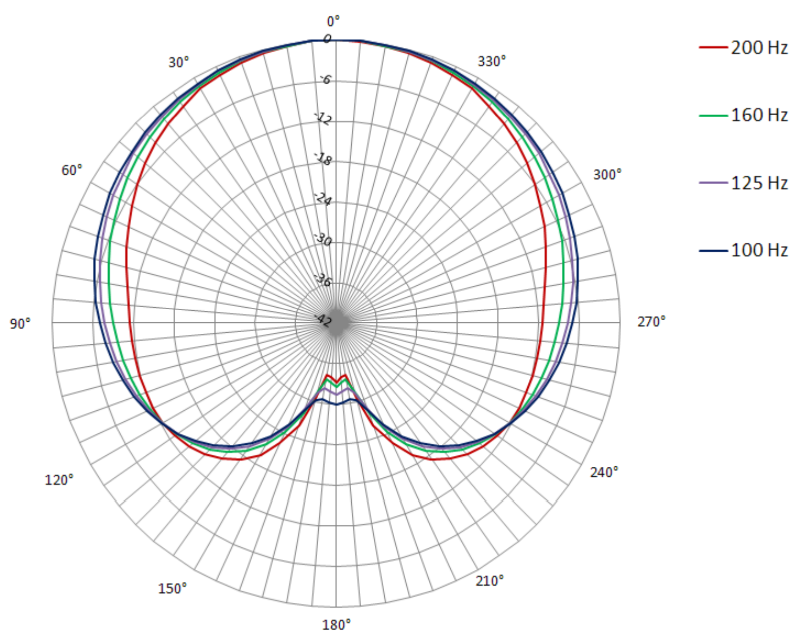
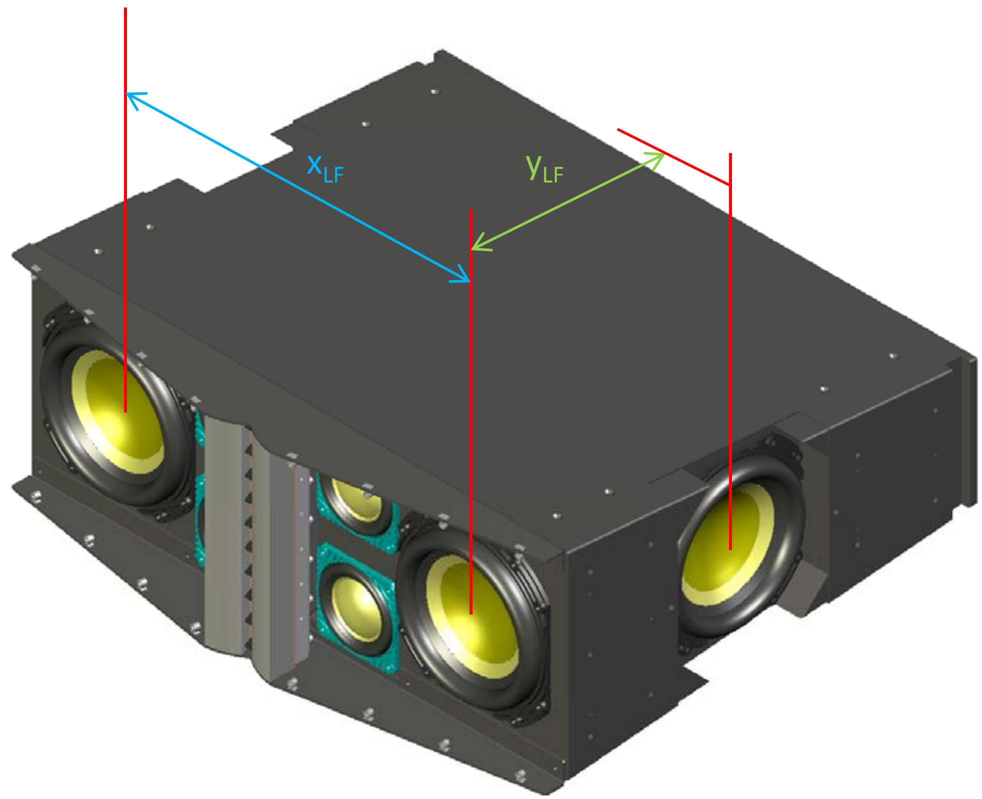
Designing For Directivity

Example driver geometry of a line array loudspeaker for good horizontal directivity control.

With additional woofers offset from the front, and the right signal processing, the horizontal directivity control can be maintained to an even lower frequency.





x = 0.5m (20 in.) y = 0.4 m (16 in.)

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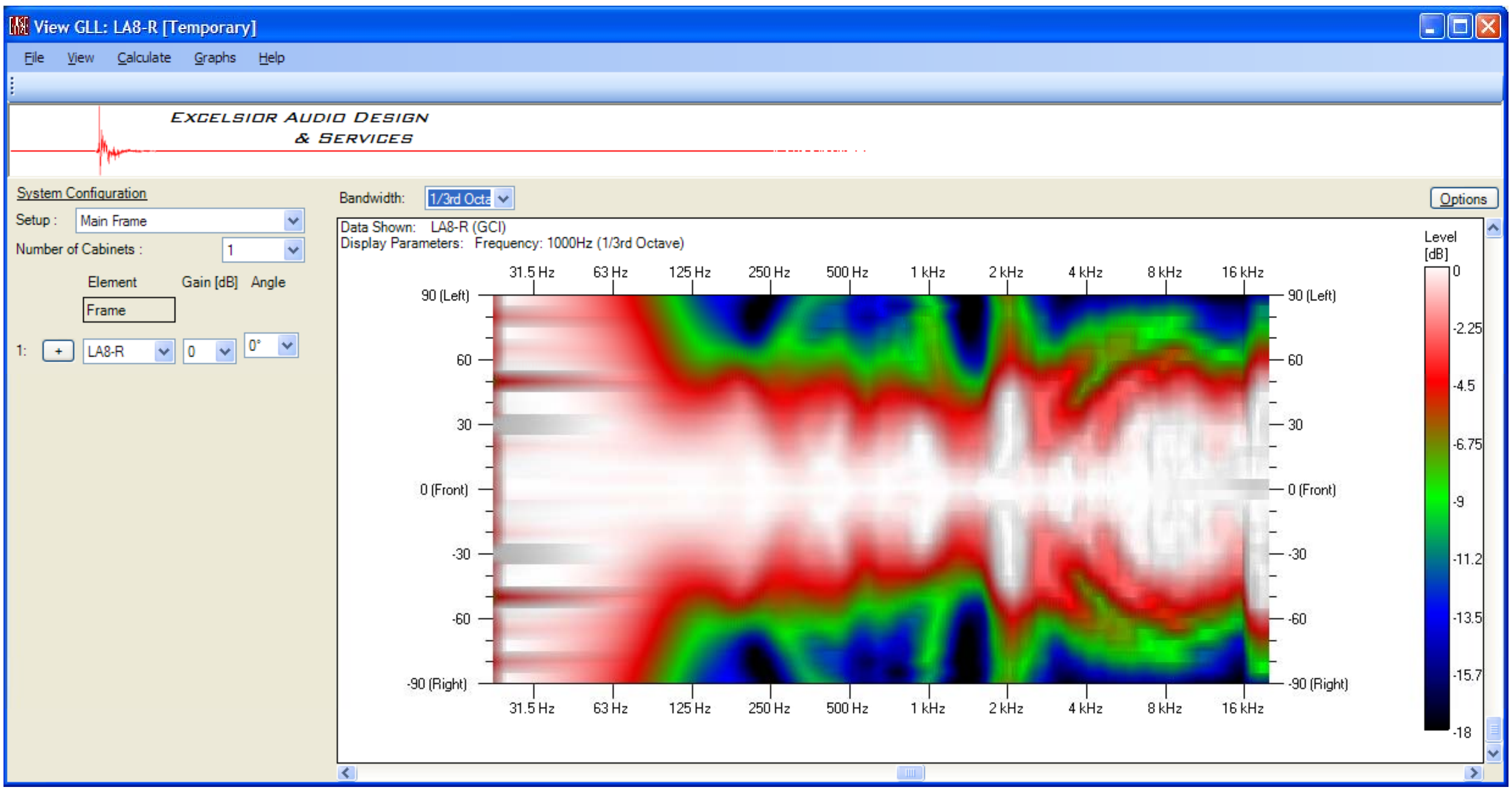
Designing For Directivity

Horizontal Directivity Map for the example line array loudspeaker

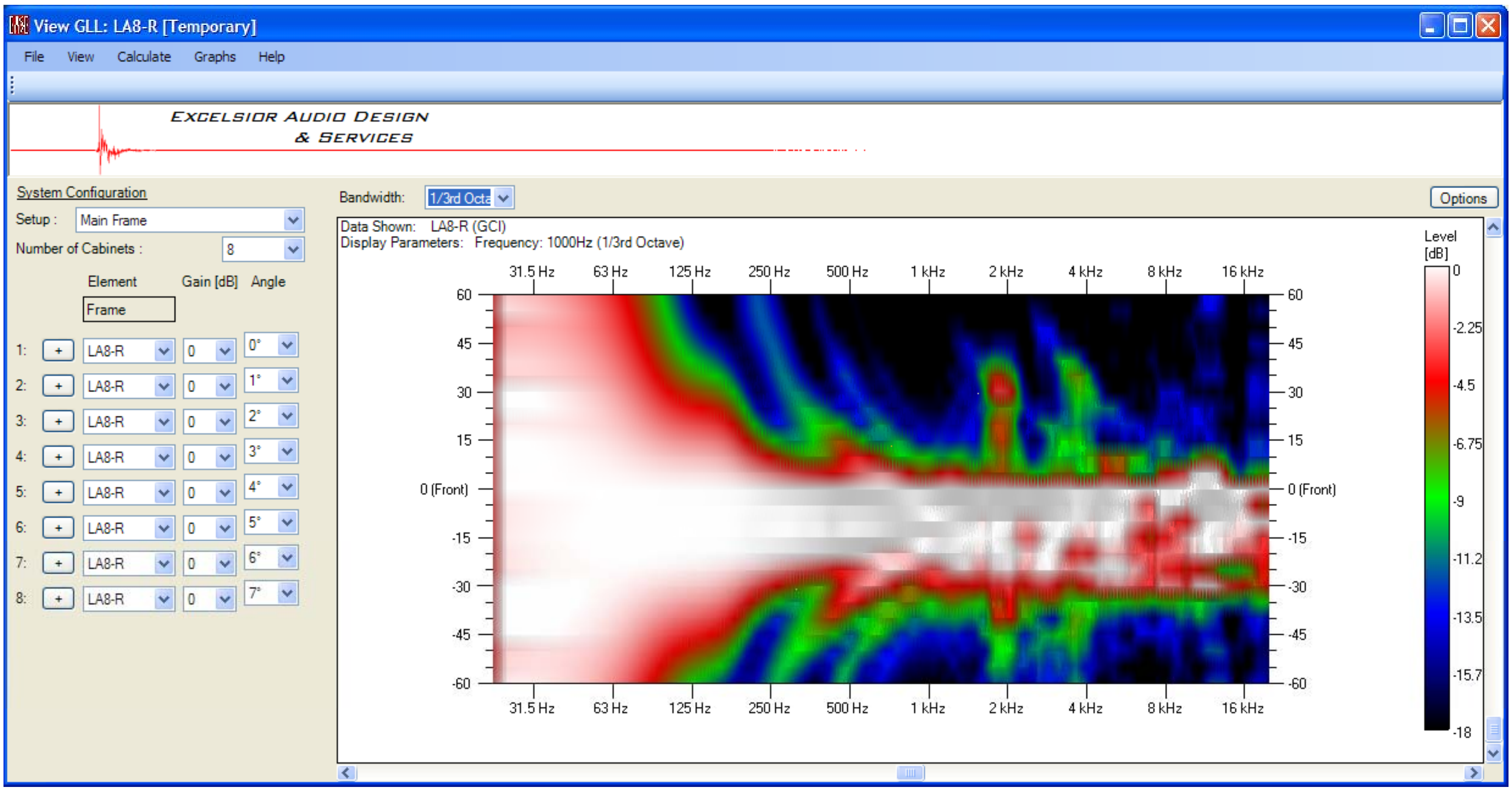
Note consistent directivity from 100 Hz – 16 kHz, with only small deviations.



Designing For Directivity

Vertical Directivity Map for the example line array loudspeaker

For an 8 box hang there is fairly consistent directivity from 200 Hz – 16 kHz, with only small deviations over a narrow bandwidth.



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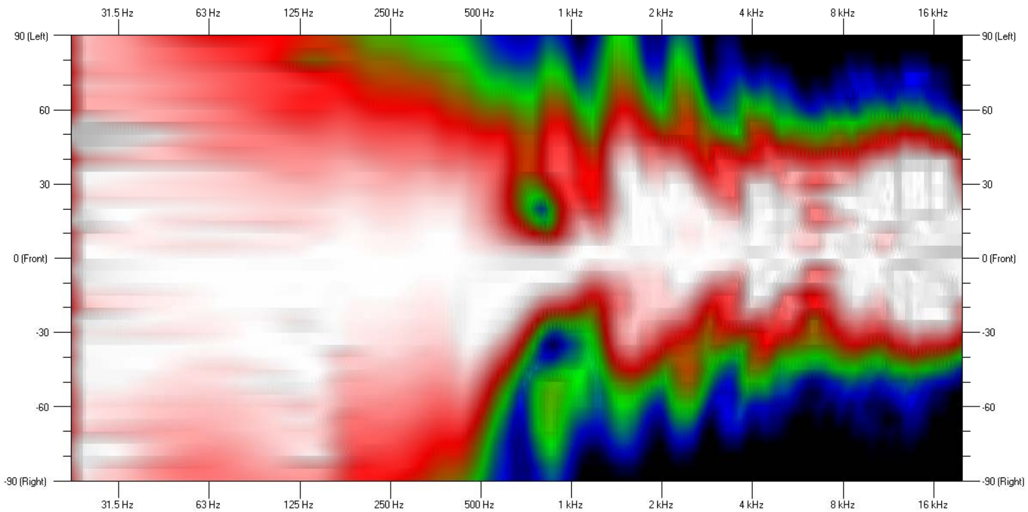
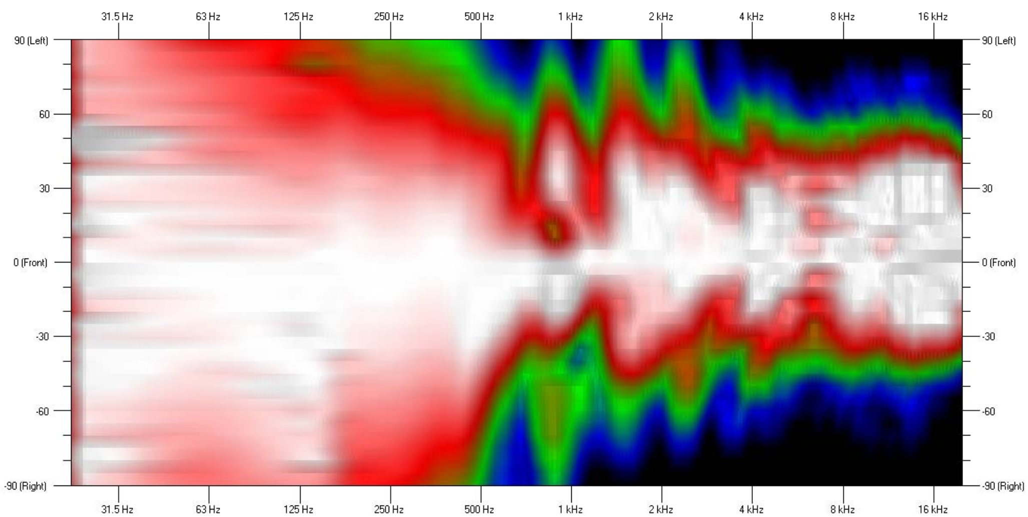
Damage Control

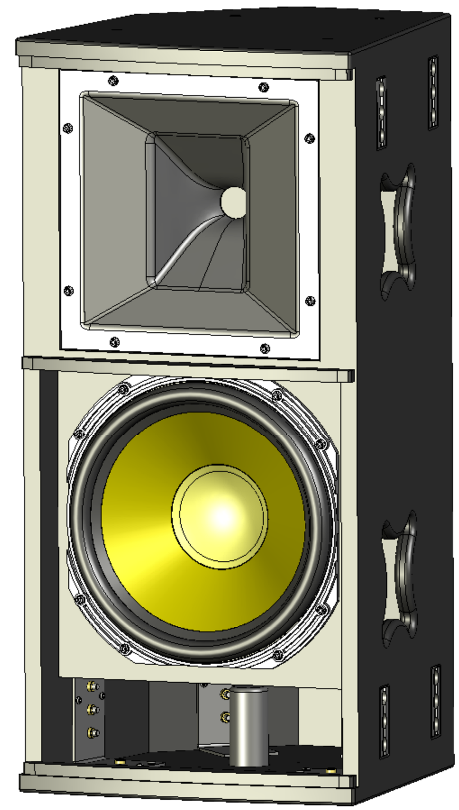
Vertical Directivity Maps for a two-way, horn & 12 inch woofer loudspeaker



Initial crossover filters for good on-axis response

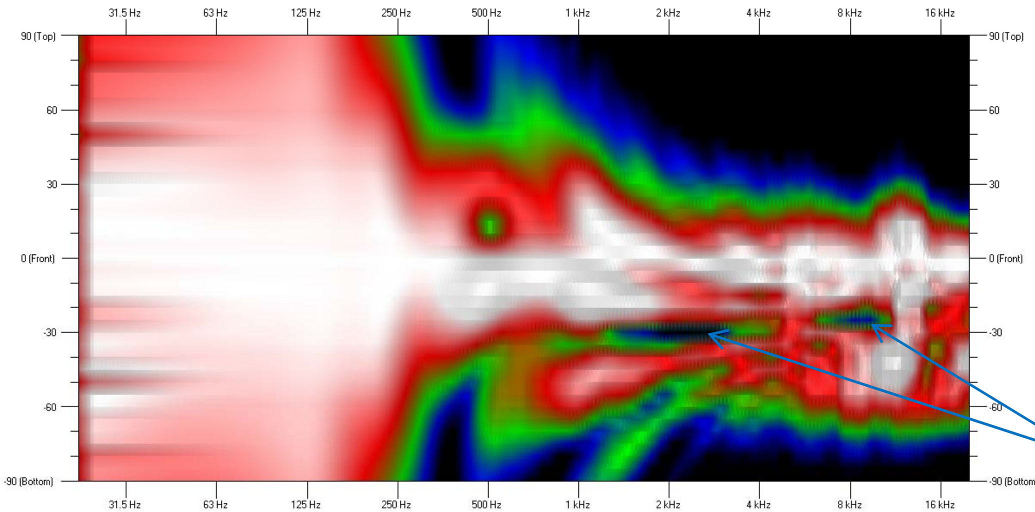


Same crossover filters but added separate parametric EQ on the LF & HF to optimize the directivity response through the crossover region



Loudspeakers in an Array

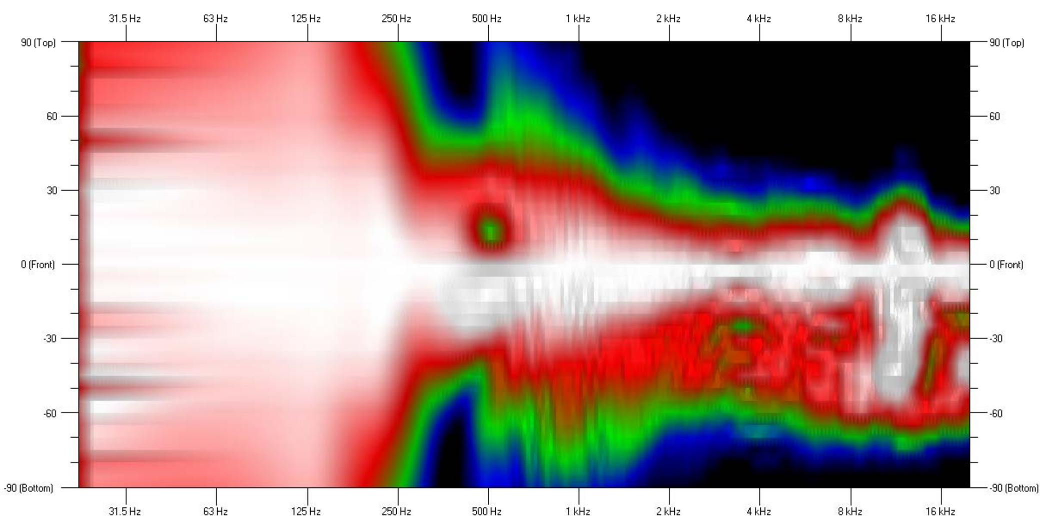
Vertical Directivity Maps for the example cluster



All filtering is the same for both directivity maps.

The down-fill is high pass filtered at approximately 900 Hz.

Note the large off-axis nulls



For this map the down-fill box is delayed 10 ms.

Directivity (and coverage) is much more consistent

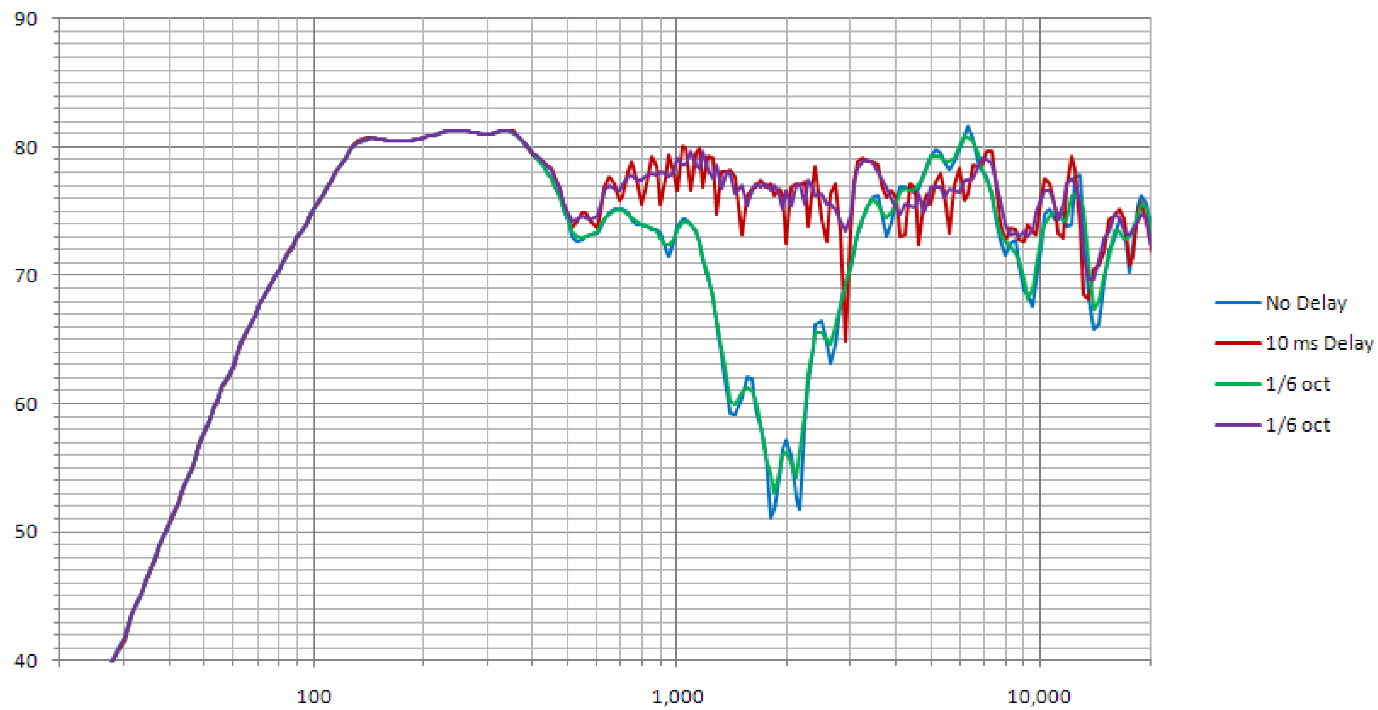
Loudspeakers in an Array

Frequency response at 30° down for the example cluster

All filtering is the same for both responses.

The down-fill is high pass filtered at approximately 900 Hz.

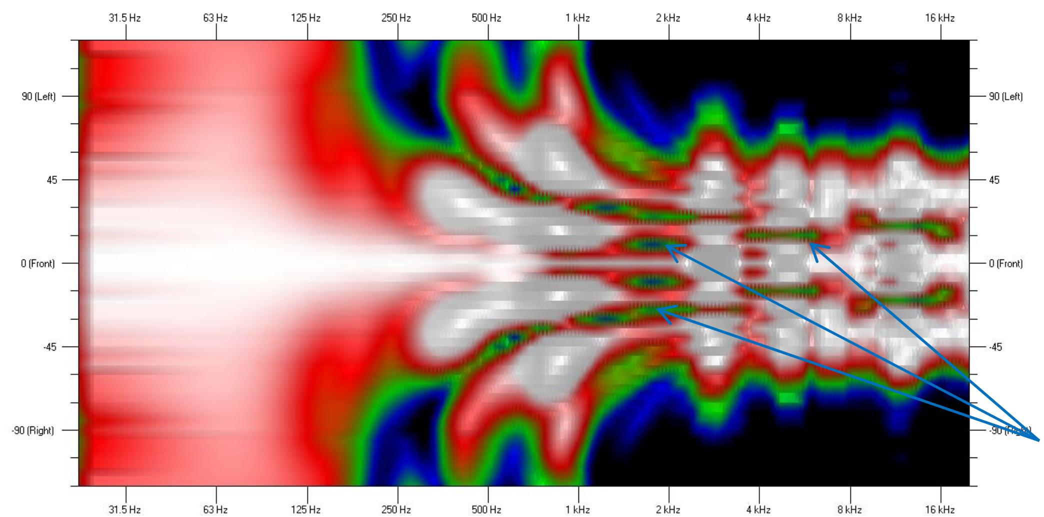
Red & purple curves are the down-fill delayed 10 ms



Blue & Red use 1/12 octave smoothing.   Green & Purple use 1/6 octave smoothing.

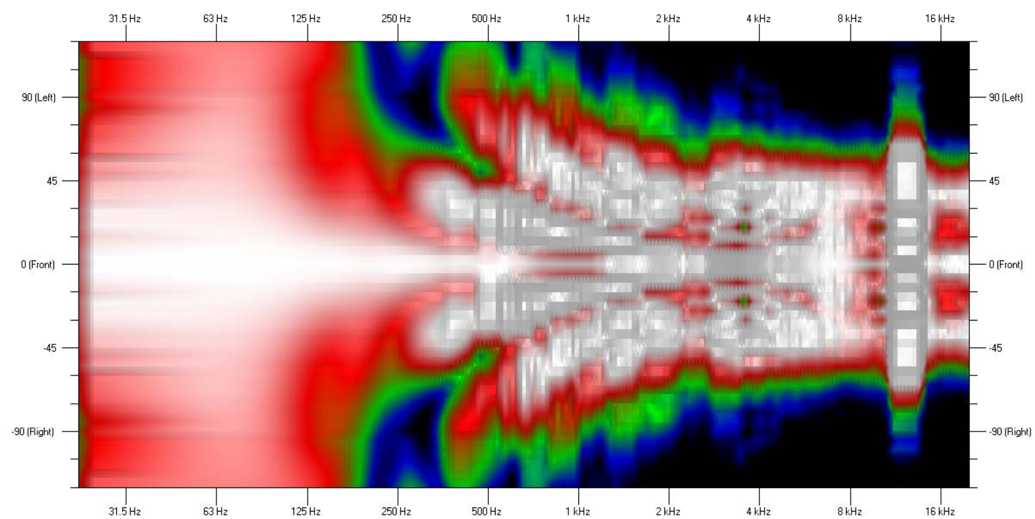
Loudspeakers in an Array

Horizontal Directivity Maps for the example cluster



All filtering is the same for both directivity maps.

Note the many, large off-axis nulls



For this map the outside mid-high boxes are delayed 10 ms relative to the center mid-high box.

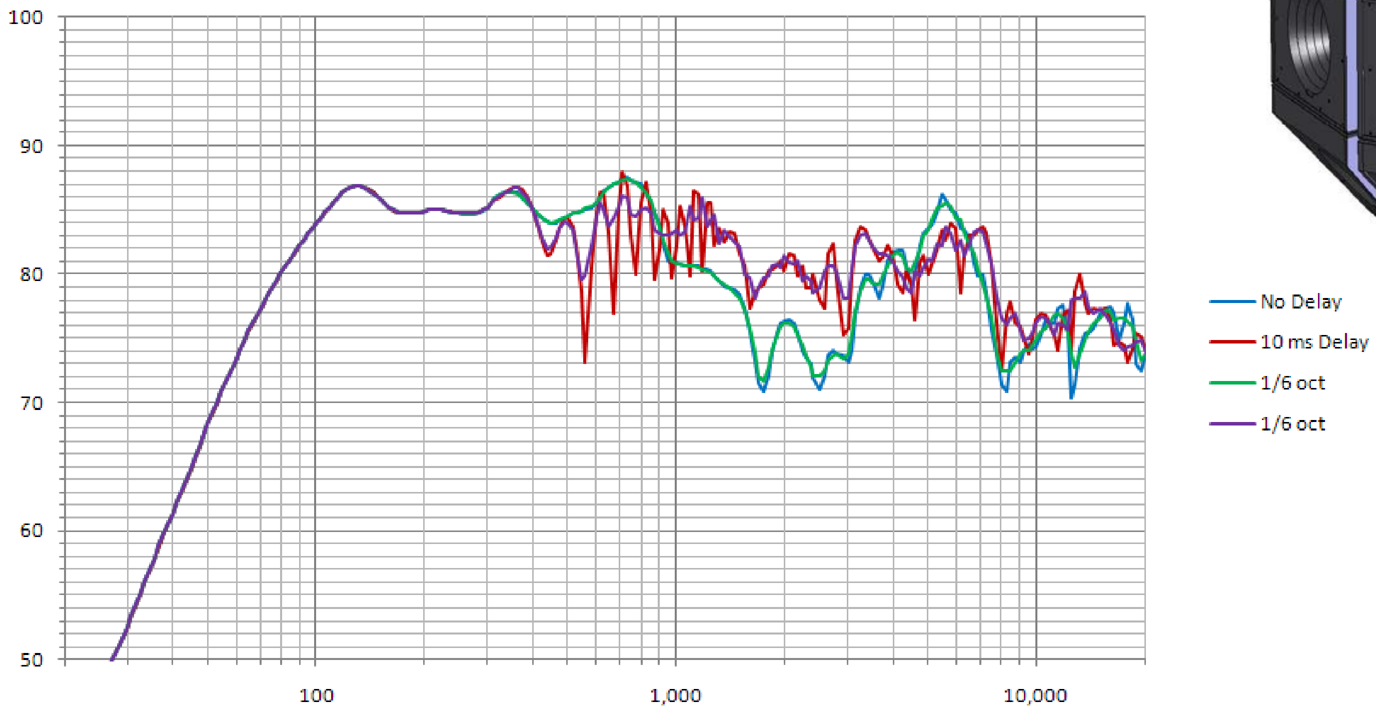
Directivity (and coverage) is much more consistent

Loudspeakers in an Array

Frequency response at 25° to the side for the example cluster

All filtering is the same for both responses.

Red & purple curves are the outside mid-high boxes are delayed 10 ms relative to the center mid-high box.



Blue & Red use 1/12 octave smoothing. Green & Purple use 1/6 octave smoothing.