AFMG

AHNERT FEISTEL MEDIA GROUP

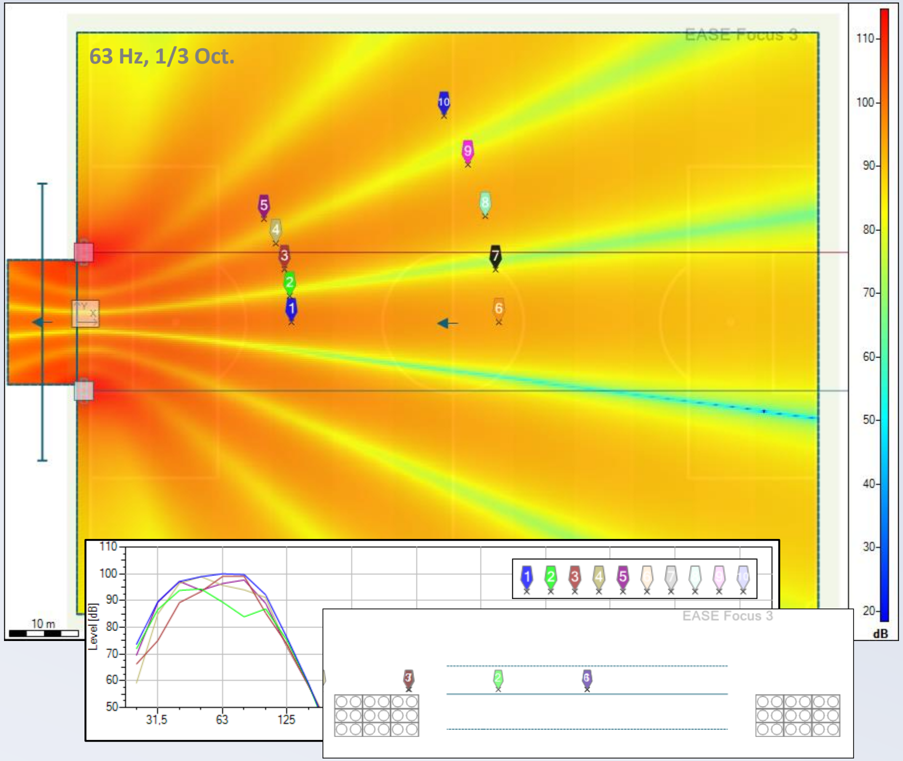
Focus Your Sub Arrays!

PLS 2017, Frankfurt

Focus Your Sub Arrays!

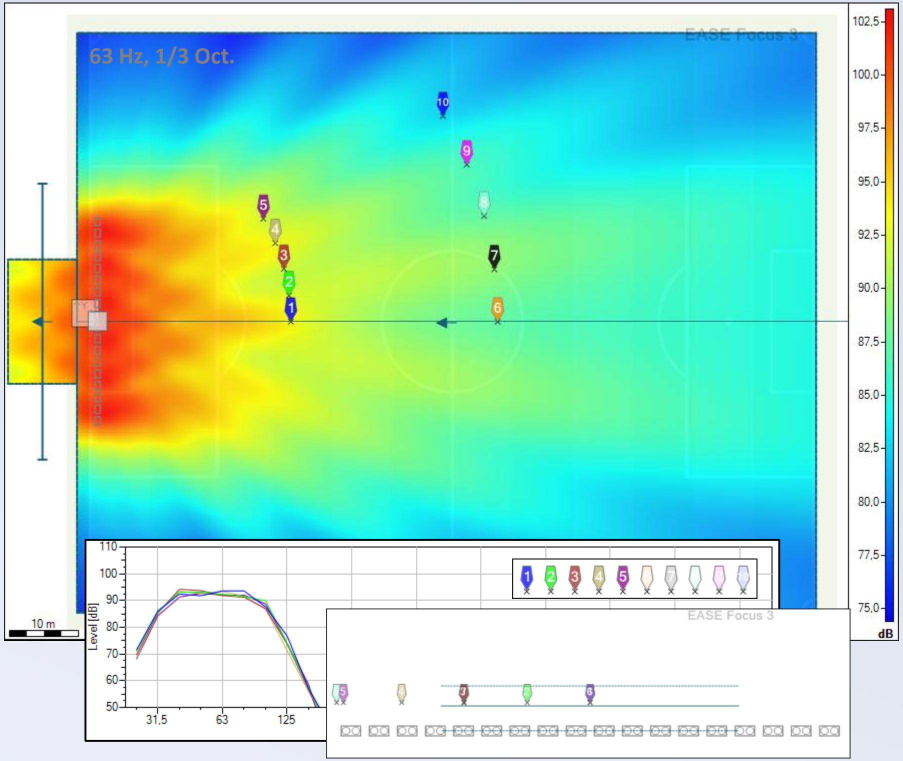
- Why Making Subwoofer Arrays?
- Design Principles
- Typical Arrays
- The Right Tools in EASE Focus 3

Why Making Subwoofer Arrays?



- Typical L-R setup
  - Large frequency response variation with seat position
  - Lack of homogeneity
  - Energy spread through undesired locations
    - More interaction with walls and sub-systems
    - High LF energy on stage

Why Making Subwoofer Arrays?



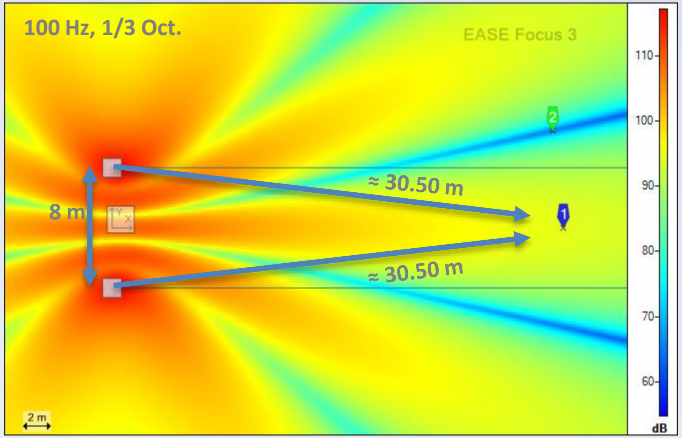
- Example of Sub Array
  - Improved frequency response consistency
    - Better low frequency reproduction quality
  - Concentration of energy where the audience actually is

Design Principles

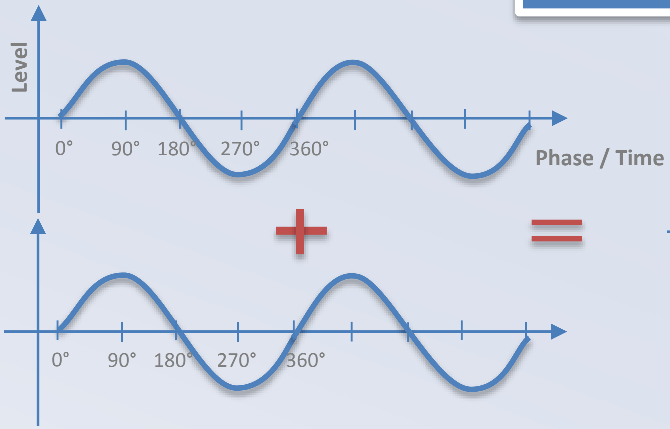
- Complex summation of sound waves
  - Practical example

1 + 1 = ?

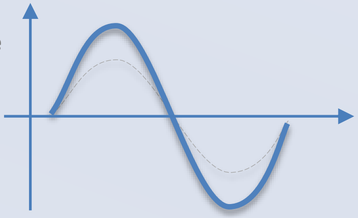
It depends on the phase difference.



Free field simulation.



Arrival at the same time (no phase difference), with same level.

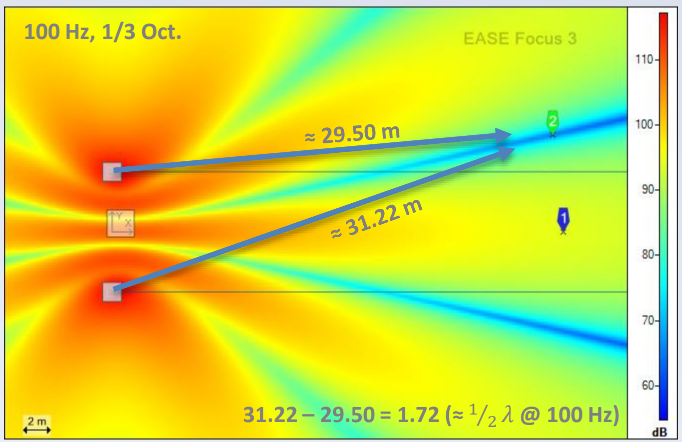


Approx. 6 dB of gain.

Design Principles

- Complex summation of sound waves
  - Practical example

1 + 1 = ?
It depends on the phase difference.



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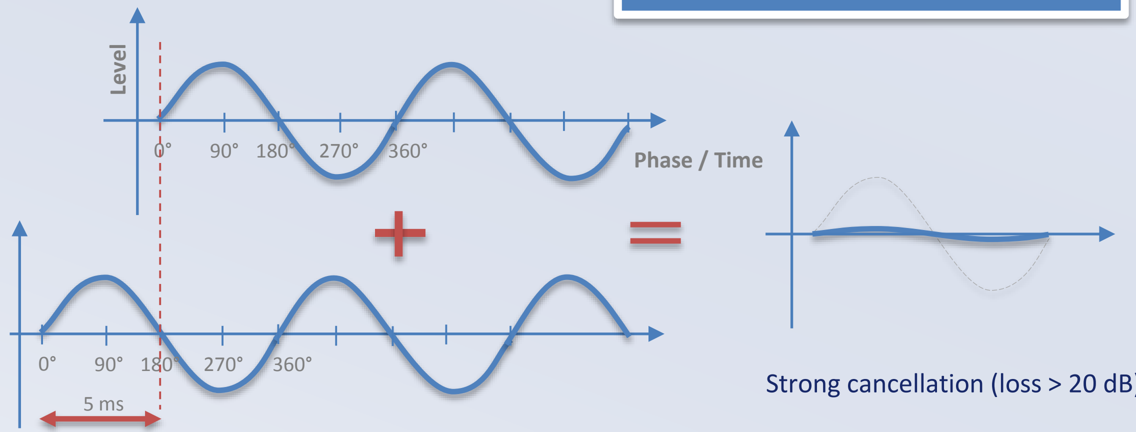


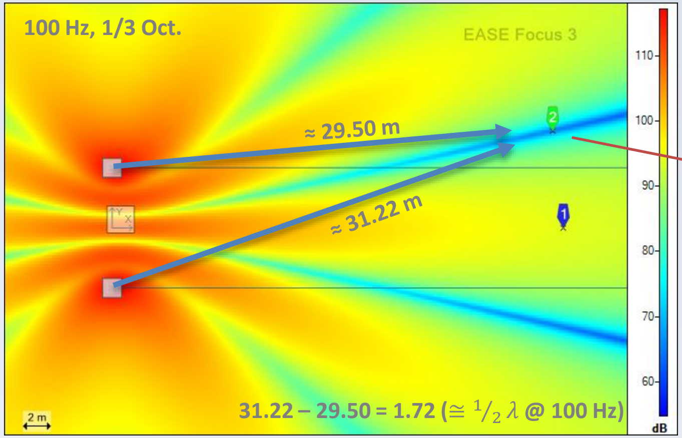
Arrival at different times (**180° phase difference**), with approx. same level.

Strong cancellation (loss > 20 dB)

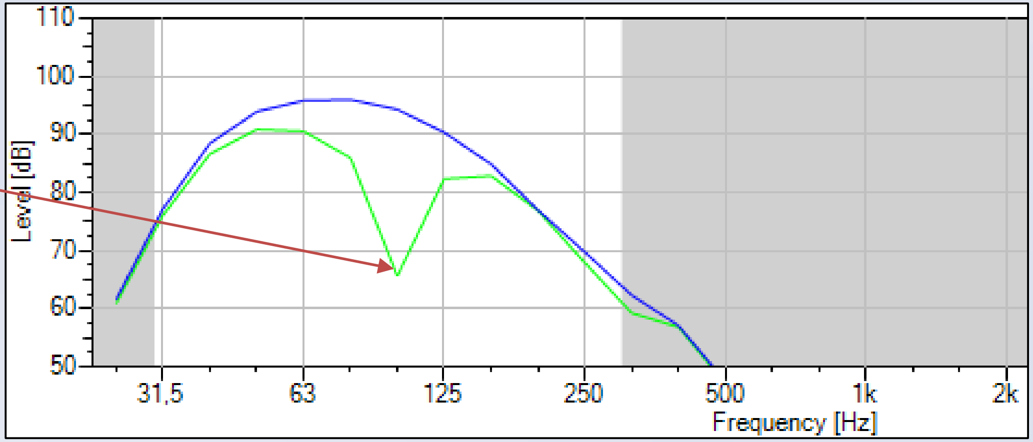
For $f = 100$ Hz:
$\lambda \cong 3.43\ m$ (@ 20°C), T = 10 ms

Design Principles

- Complex summation of sound waves
  - Practical example



Free field simulation.



Frequency response at the two microphone positions.

For $f = 100$ Hz:
$\lambda \cong 3.43\ m$ (@ 20°C), T = 10 ms

Design Principles

- Complex summation of sound waves
  - Explore this behavior and make it work in your favor
  - Shift the zones where cancellations occur by repositioning the loudspeakers and applying delay times appropriately
  - Different setups can be used depending on application

Design Principles

- Speed of Sound in Air
  - It is not dependent on frequency or amplitude
  - Also largely independent on atmospheric pressure in typical applications
  - Mostly dependent on temperature, only!

$$c = c_0\sqrt{1 + \vartheta/273} \quad [\mathrm{m/s}],$$

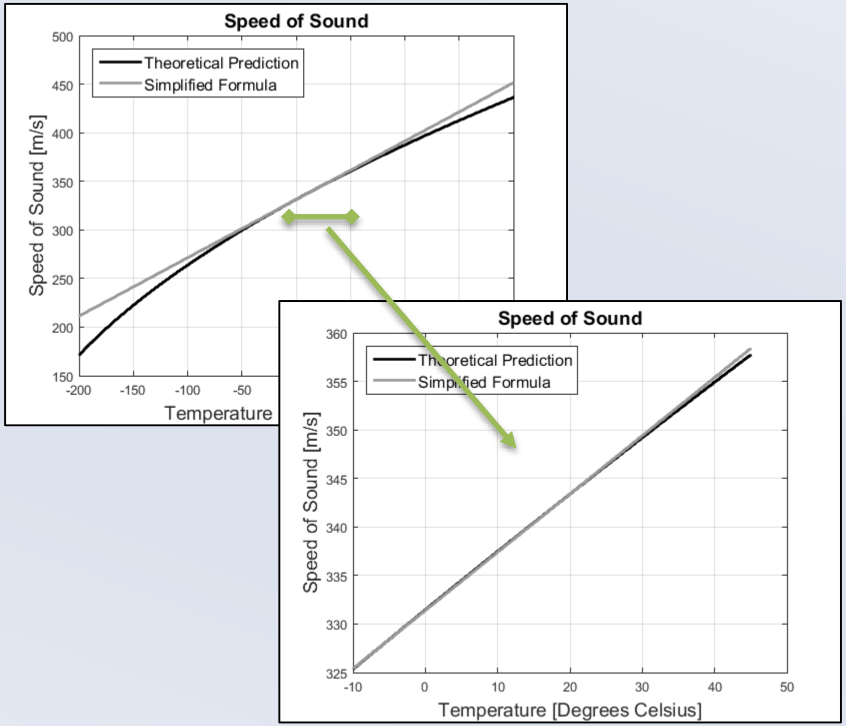
where c_0 is the speed of sound at 0°C ≈ 331.46 m/s and ϑ is the temperature in °C.

Design Principles

- Speed of Sound in Air
  - Simplified equation for sound reinforcement applications:

$$c \approx 331.4 + 0.6\,\vartheta \quad [\mathrm{m/s}],$$

where ϑ is the temperature in °C.



Design Principles

- Wavelength λ:
  - Calculate from the speed of sound and frequency of interest:

$$\lambda = \frac{c}{f} \quad [\mathrm{m}] \qquad \lambda_{100Hz} = \frac{343.40}{100} \approx 3.43\ \mathrm{m}$$

f [Hz]	λ [m]
10	34.3
100	3.43
1000	0.34

- Period of wave T

$$T = \frac{1}{f}\ [\mathrm{s}] \qquad T_{100Hz} = \frac{1}{100} \approx 10\ \mathrm{ms}$$

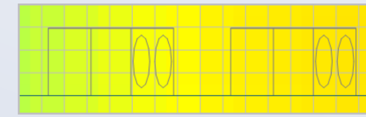
f [Hz]	T [ms]
10	100
100	10
1000	1

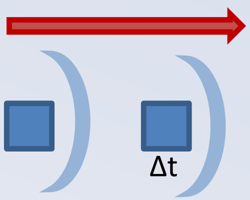
Typical Arrays

- Cardioid (2x)
- Cardioid (2x) with Inverted Polarity
- Cardioid (3x) Side-by-Side
- Cardioid (3x) Stack
- End-Fire
- Linearly Arranged Subwoofers

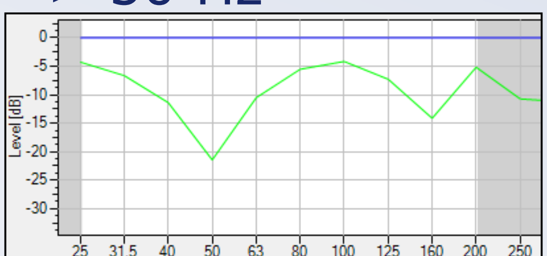
Cardioid (2x)

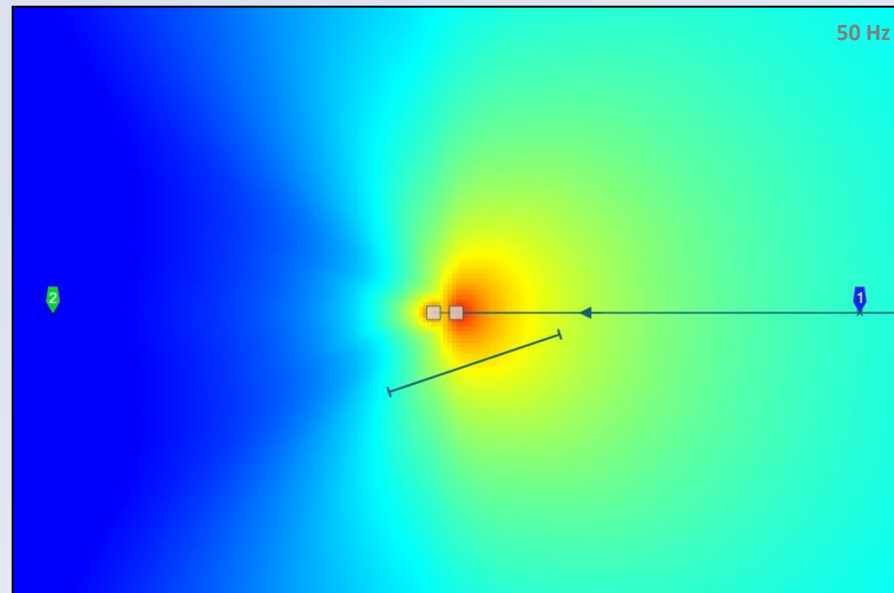
- Two subs spaced ¼ wavelength
- Front sub delayed by ¼ cycle
- Approximate cardioid pattern at frequency of choice





E.g. 1.7 m, 5 ms delay
=> 50 Hz





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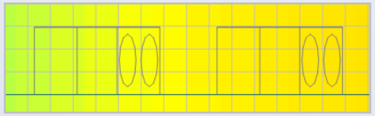

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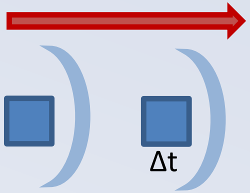

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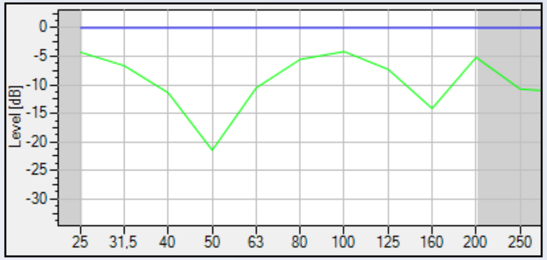
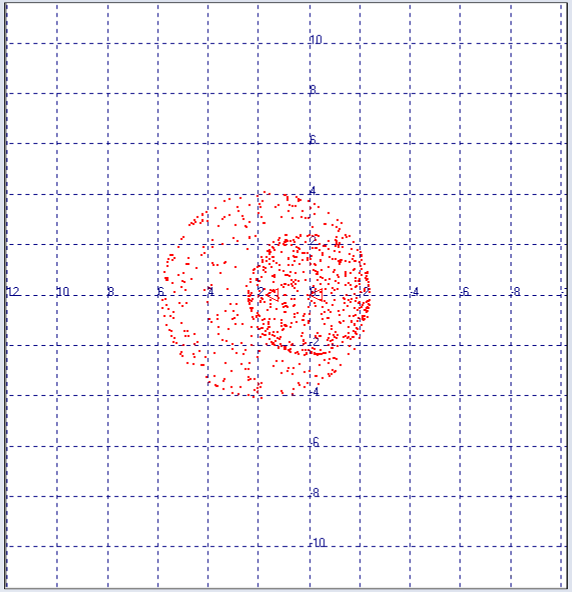
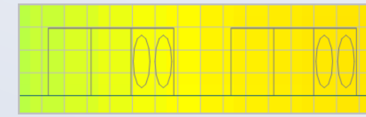
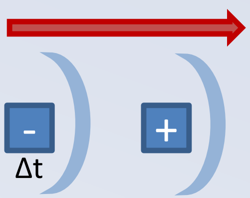




Cardioid (2x) with Inverted Polarity

- Two subs spaced ¼ wavelength
- Back sub delayed by ¼ cycle, inverted polarity
- Approximate cardioid pattern, also for lower frequencies





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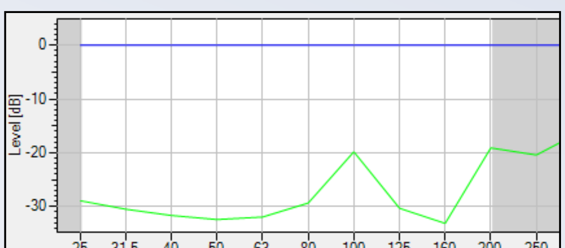
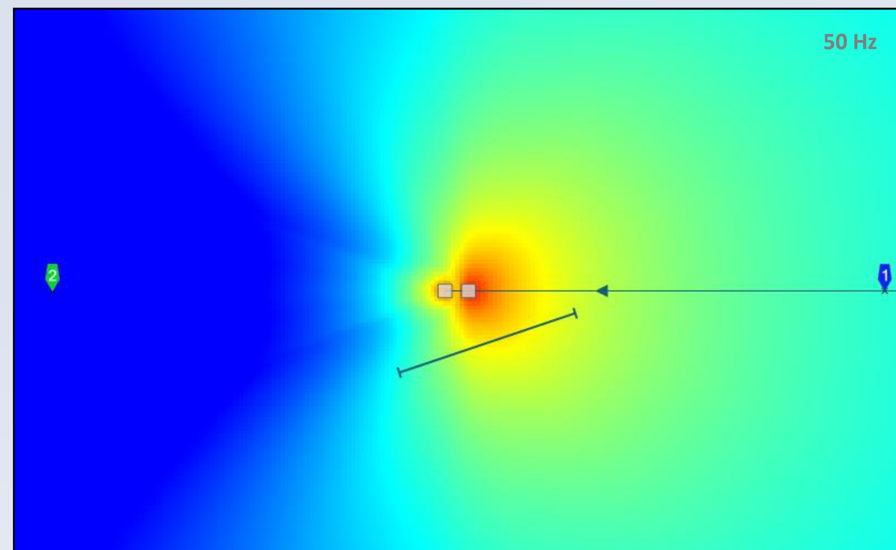
=> 50 Hz and below





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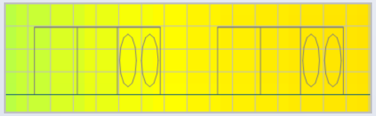

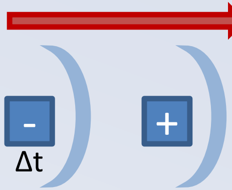

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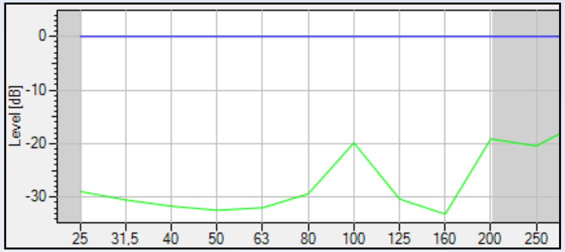
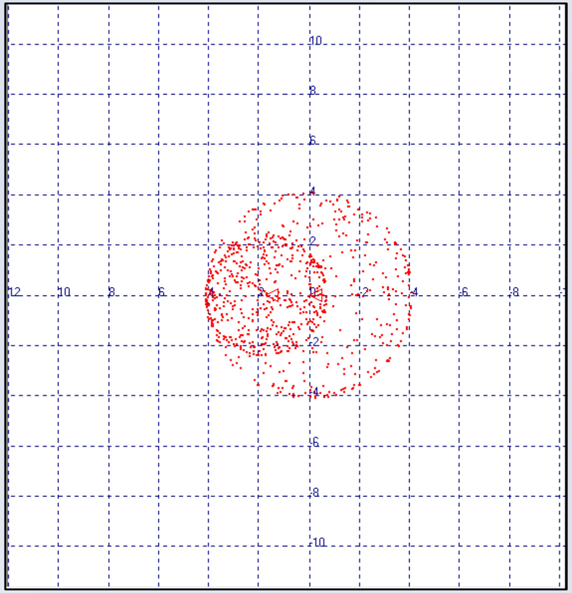
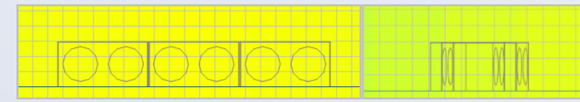
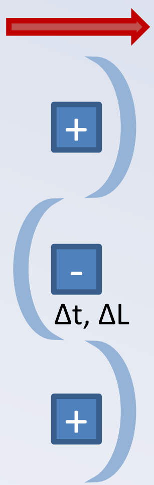


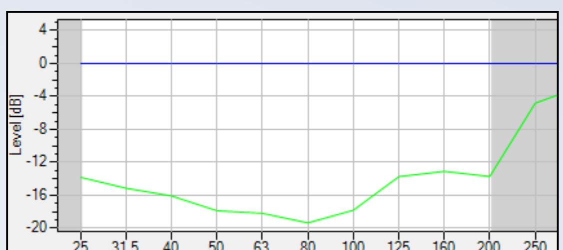


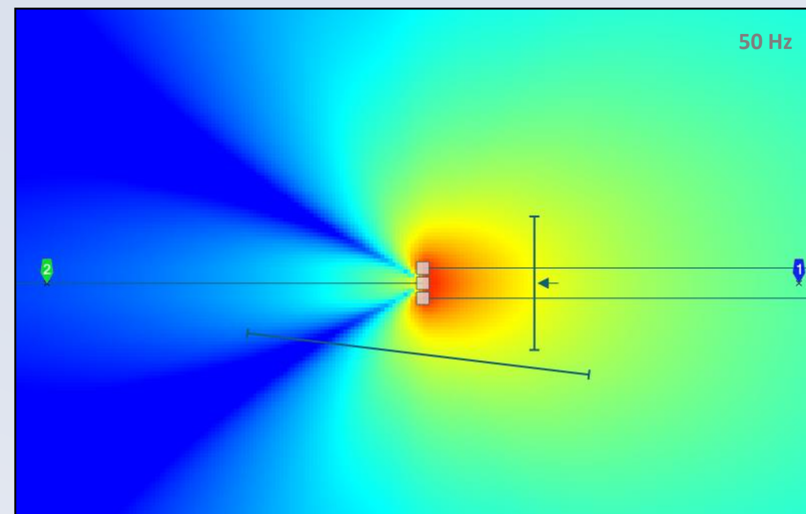
Cardioid (3x) – Side-by-Side



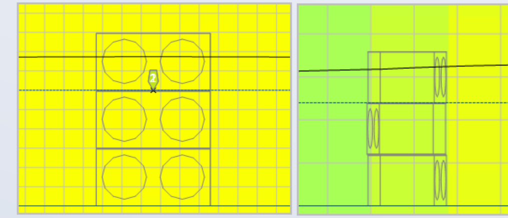
- Three subs side-by-side
- Center sub aimed backward, inverted polarity
- Adjust gain & delay of inverted sub for optimal cardioid pattern
- No gain needed when sub has 6 dB front-to-back attenuation







Cardioid (3x) – Stack



- Three subs stacked
- Center sub aimed backward, inverted polarity
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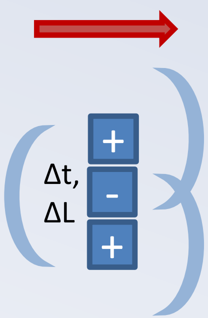
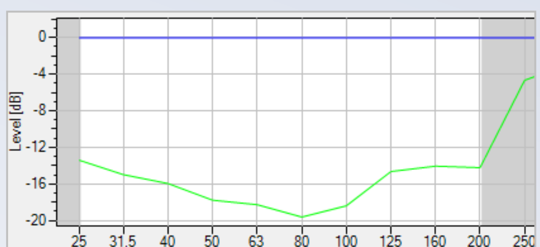
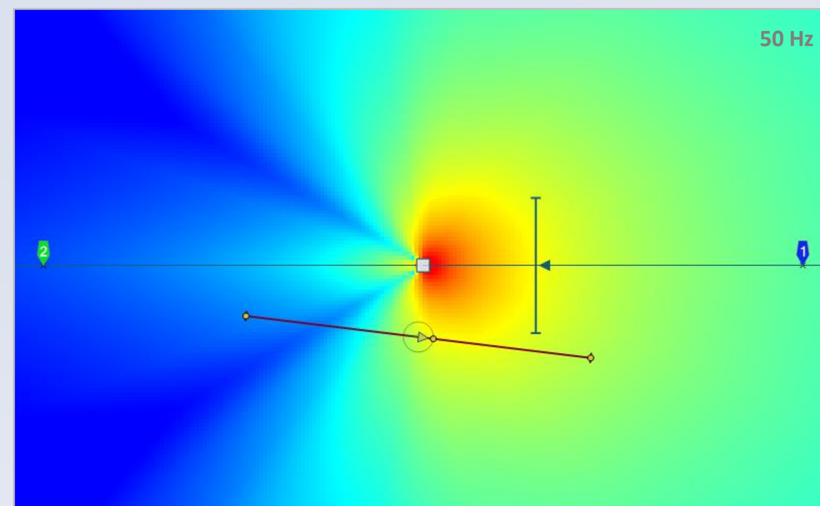
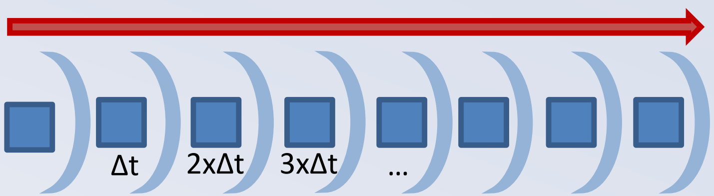




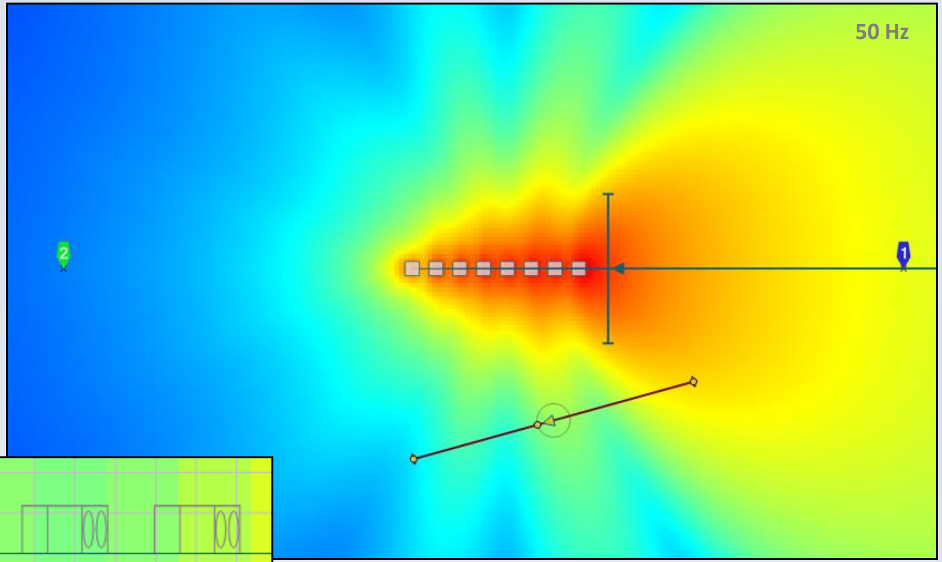


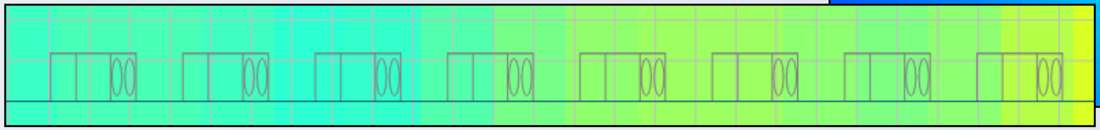
End-Fire

- Elements arranged along the axis of the array
- Aligning the wave fronts in time yields shotgun pattern
- Spacing determines delay and frequency of optimal suppression of backward radiation



E.g. 1.7 m, 5 ms Delay





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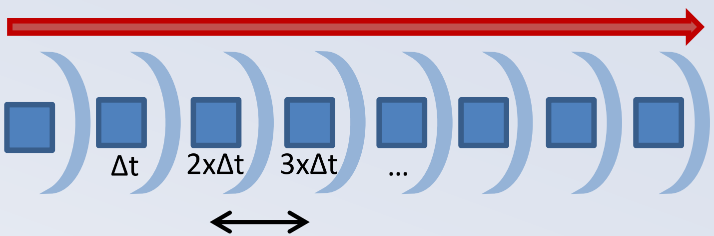

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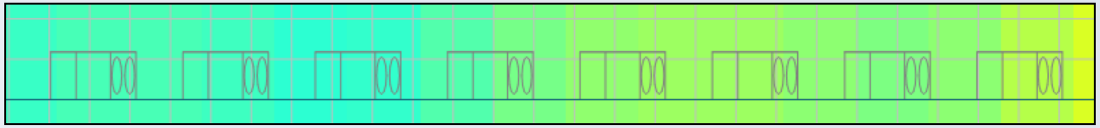

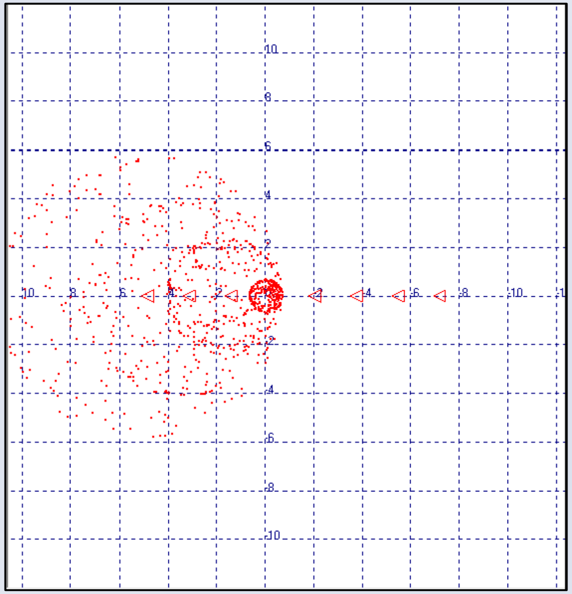

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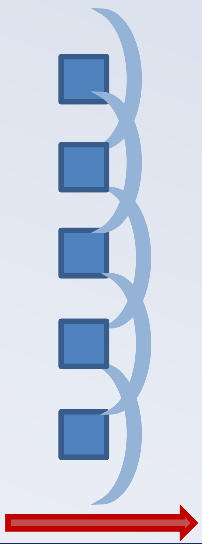
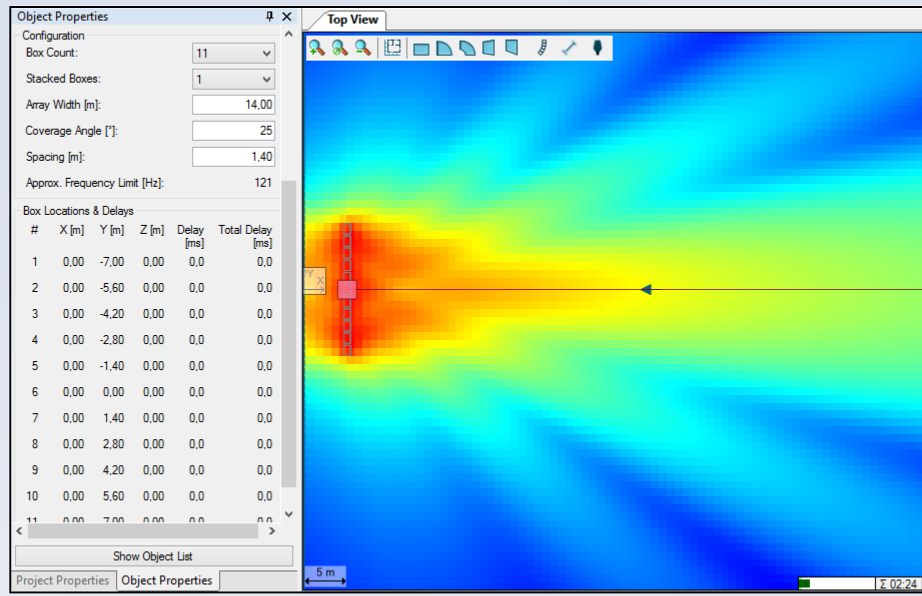
Pre-Configured Linear arrays

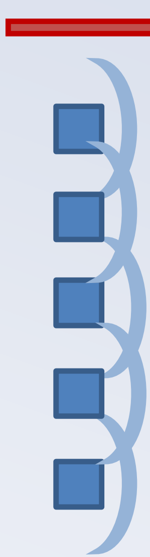
- Elements arranged along a line perpendicular to radiation axis
- Spacing between elements determine max. upper frequency to be controlled
  - Should not exceed $^1/_2\,\lambda$ of the upper crossover frequency, in general
- The array length is approximately one wavelength of the lowest frequency to be controlled

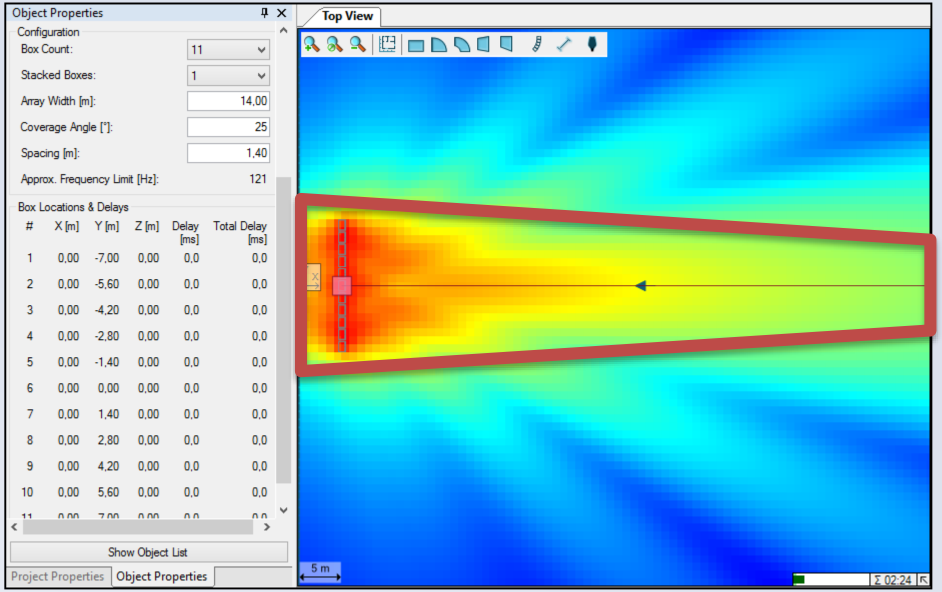




Pre-Configured Linear arrays

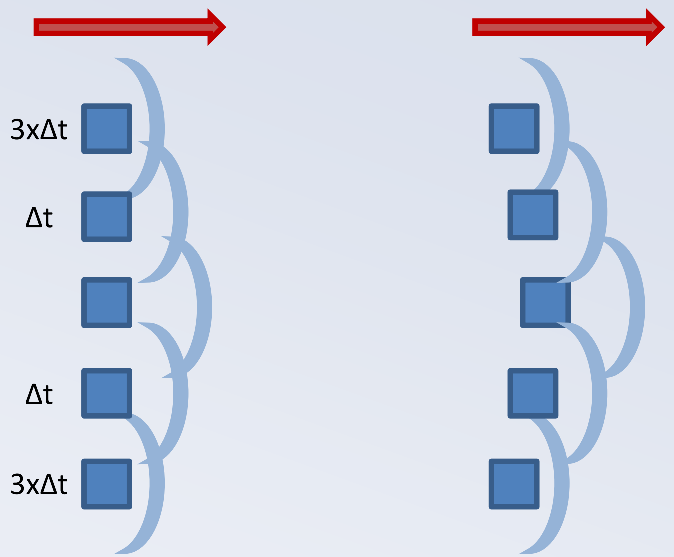
- However, the longer the array the narrower its opening angle

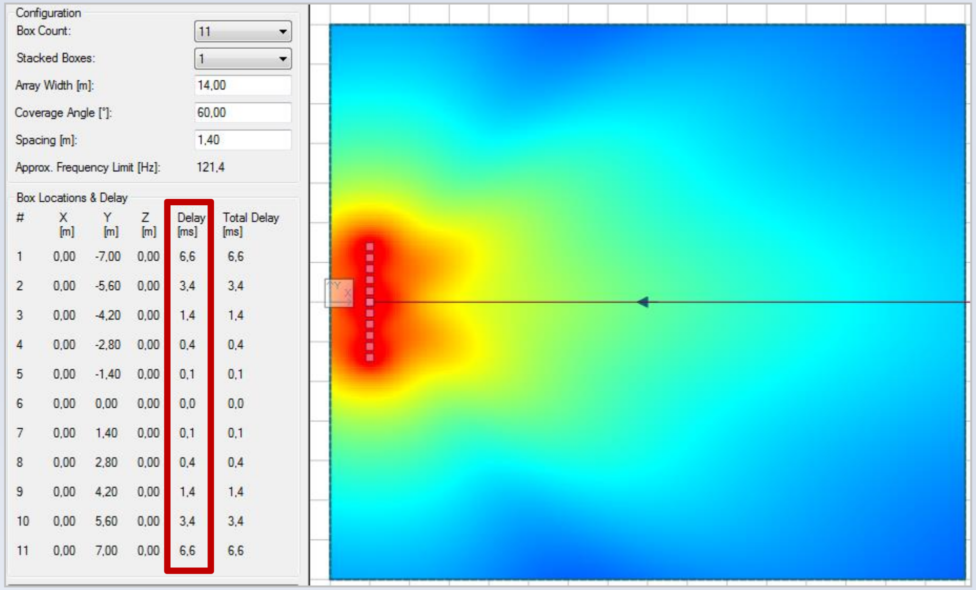




Pre-Configured Linear arrays

- Template: Linear arrangement with user-defined coverage angle
- Using delay times <u>automatically calculated by EASE Focus</u> for outer subs allows widening the opening angle
  - Similar effect can be accomplished by manually positioning the elements in an arc





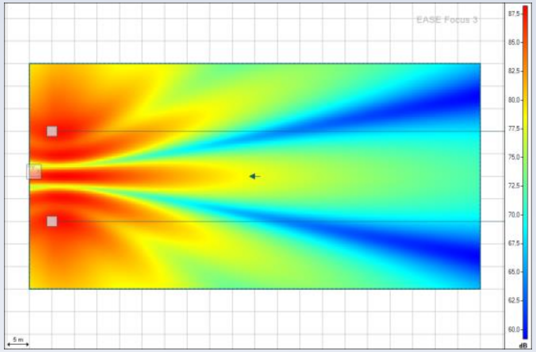
#	X [m]	Y [m]	Z [m]	Delay [ms]	Total Delay [ms]
1	0,00	-7,00	0,00	6,6	6,6
2	0,00	-5,60	0,00	3,4	3,4
3	0,00	-4,20	0,00	1,4	1,4
4	0,00	-2,80	0,00	0,4	0,4
5	0,00	-1,40	0,00	0,1	0,1
6	0,00	0,00	0,00	0,0	0,0
7	0,00	1,40	0,00	0,1	0,1
8	0,00	2,80	0,00	0,4	0,4
9	0,00	4,20	0,00	1,4	1,4
10	0,00	5,60	0,00	3,4	3,4
11	0,00	7,00	0,00	6,6	6,6

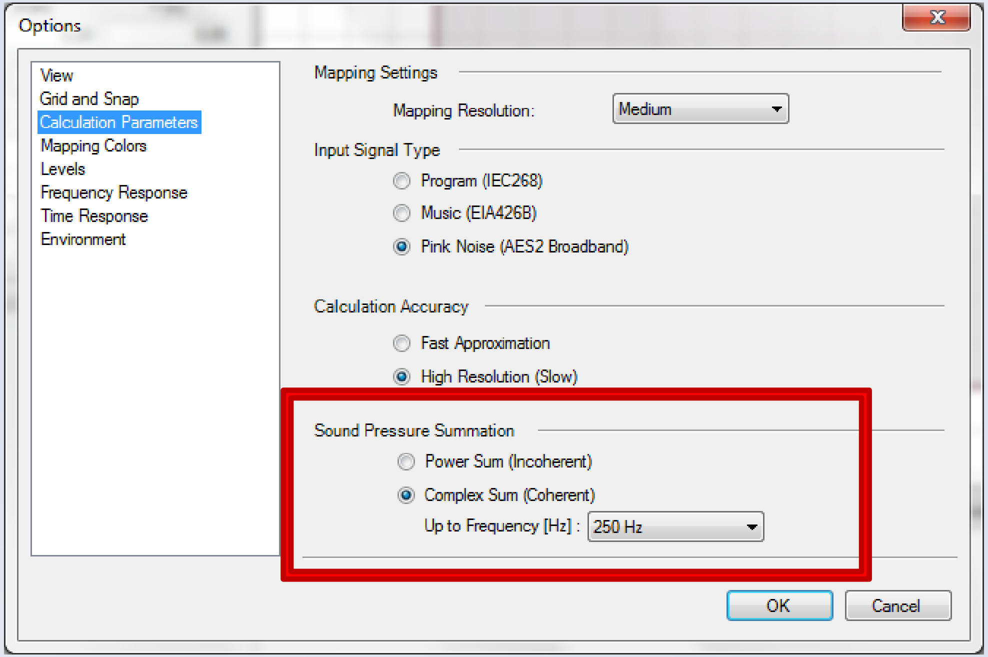
The Right Tools in EASE Focus 3

- Calculation Engine
  - Complex Summation
  - User-Defined Subwoofer Arrays
  - Pre-Configured Subwoofer Arrays
- Manipulating Loudspeakers
  - Gain, Delay, Polarity and Filter Settings for Single Sources
  - Moving and Turning Groups
  - Stacking and Snapping Functions

Sound Pressure Summation

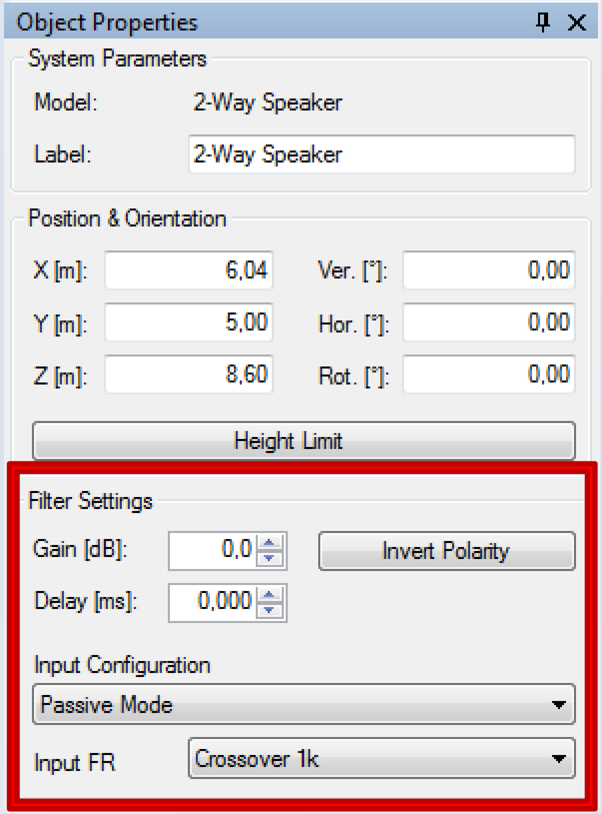
- Total sound pressure of multiple sources can be summed coherently up to a selected frequency.
- Allows modeling manually arranged sub arrays etc.





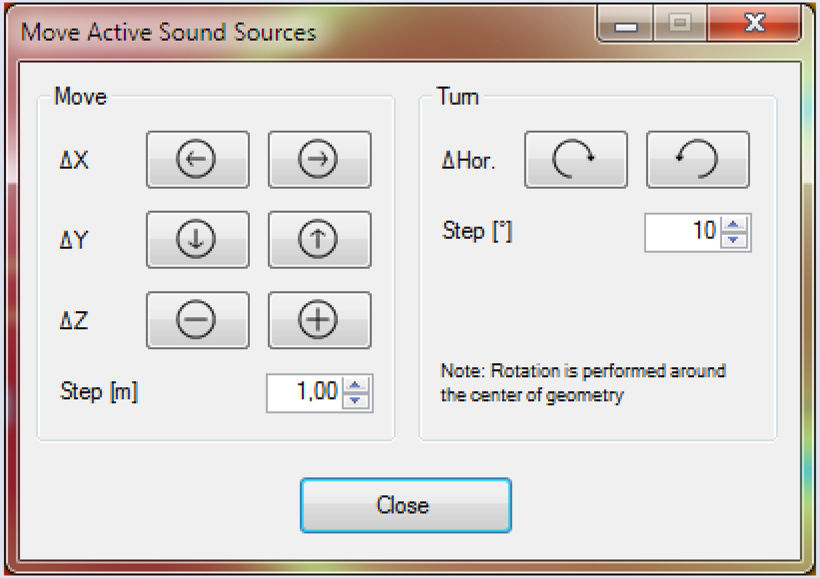
Gain, Delay, Polarity for Single Sources

- Settings for single loudspeakers and subs:
  - Gain
  - Delay
  - Polarity
  - Filters
- Useful for building and optimizing arrays of sources.



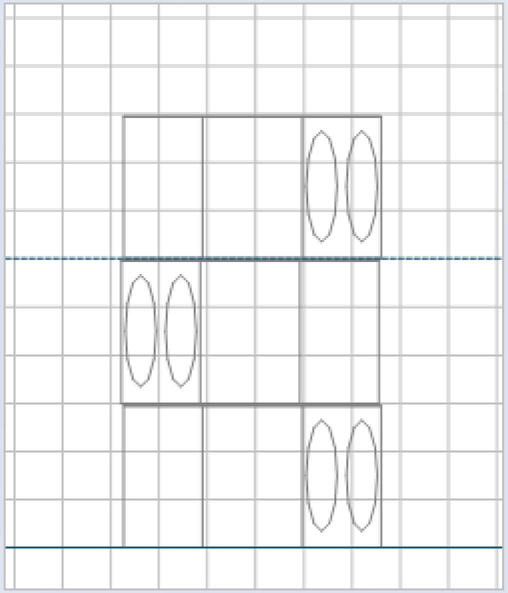
Move Groups of Sources

- Sound source groups:
  - Move along X-, Y-, Z-axis
  - Turn horizontally about Z-axis
- Fast displacement and aiming of entire sub arrays or clusters.



Stack Loudspeakers

- Stack loudspeakers easily.
- Snap to bottom loudspeaker or ground.
- Useful for subwoofer arrays or tops on subs.



For that, hold Ctrl key while dragging the loudspeaker in the Top View.

Focus Your Sub Arrays!

- Summary
  - Improve low frequencies control by using subwoofer arrays
  - Shape your array coverage by designing different setups with the same principles
  - Use EASE Focus 3 as the perfect tool for your designs!

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