professional german loudspeaker systems

Voice-Acoustic User Guide

Directional
Subwoofer Configurations

Instructions and useful information
Stand V1.0, Juli 2025

Voice-Acoustic User Guide
Directional Subwoofer Configurations

Introduction

Since subwoofer enclosures are significantly smaller than the wavelength of their reproduction range (25 Hz to 100 Hz corresponds to a wavelength of approx. 13.7 m to 3.4 m), subwoofers have only a low directivity and emit sound in an almost spherical (omnidirectional) pattern. Behind subwoofers, it is therefore almost as loud as in front of them. In some cases, precise directivity is desired, for example to minimise noise emissions. Significant directivity can be achieved through certain array configurations. For easy implementation, two different cardioid array setups are preconfigured in the VADAS and HDSP power amplifiers for all Voice-Acoustic subwoofers.

CSA**G**-mode is optimised for the best possible directivity with maximum rear attenuation and corresponds to what is often referred to as a 'cardioid subwoofer array' (CSA) or "**G**radient array". The addition and thus the sound pressure to the front is lower than with standard setups where all subwoofers radiate to the front.

CSA**E-**mode is optimised for the best possible forward reproduction quality and has less pronounced directionality. CSAE-mode corresponds to what is often referred to as an "**E**nd-Fire array". End-Fire arrays are often implemented using several rows of subwoofers in succession. However, our preconfigured arrays correspond to the same setup as the CSAG-mode mentioned above, with two subwoofers facing forward and one facing backward. The implementation of an end-fire array in this configuration is also called an "inverted stack array".

Setup

All preconfigured loudspeaker presets for directional cardioid subwoofer array are based on the same setup.

The setup consists of three subwoofers, with the middle one normally facing backwards. The loudspeaker presets are optimised for vertical stacks (illustration on the right), but can also be set up horizontally in an upright position.

If several stacks are operated side by side, there must be a gap of at least 40 cm between the stacks. The stacks should be positioned at least 1 m away from the wall.

Further possible setup variants for specific applications are shown on page 3.

Caution: never use CSAG and CSAE presets together!

CSA**G**-Mode Preset

Standard top preset

Standard preset

CSAG-rear preset

Standard preset

CSA**E**-Mode Presets

Standard top preset
+ 4 ms (1,38 m) Delay

CSAE-front preset

CSAE-rear preset

CSAE-front preset

CSAG-Mode

The loudspeaker presets in CSAG-mode are designed for stacks consisting of three identical subwoofers. Normally, the three subwoofers are stacked on top of each other, with the middle subwoofer facing backwards. Two power amplifier channels are required per stack. The front-facing subwoofers are operated with the **"Standard"** preset. The rear-facing subwoofer is used with the **"CSAG Rear"** preset.

A delay for the top units or line arrays relative to the standard preset is not necessary in CSAG-mode.

CSAE-Mode

The loudspeaker presets in CSAE-mode are designed for stacks consisting of three identical subwoofers. Normally, the three subwoofers are stacked on top of each other, with the middle subwoofer facing backwards. Two power amplifier channels are required per stack. The rear-facing subwoofer is operated in the **"CSAE Rear"** preset and the front-facing subwoofers in the **"CSAE Front"** preset.

Caution: In CSAE-mode, the top units or line arrays used must be delayed by **4 ms (1,38 m)**!

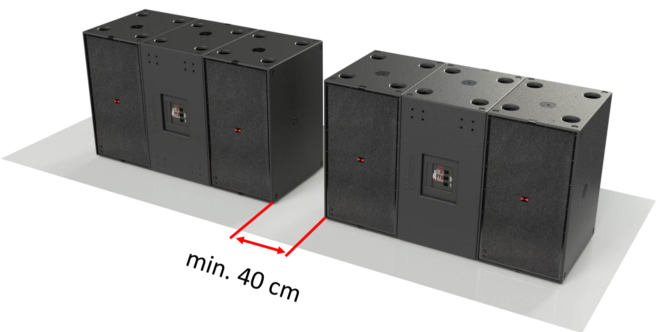
Selection: Standard, CSAG-Mode and CSAE-Mode

Standard-, CSAG- and CSAE-modes differ in terms of their output, dispersion characteristics and sound (see pages 4 and 5 for an explanation of the background). The following overview lists the advantages and disadvantages of the configurations. A cardioid configuration should only be used when absolutely necessary.

Configuration	Front-SPL	Sound Quality	Rear Cancellation
Standard	★★★★★	★★★★★	★★
CSAG-Mode	★★★	★★	★★★★★
CSAE-Mode	★★★★	★★★★★	★★★★

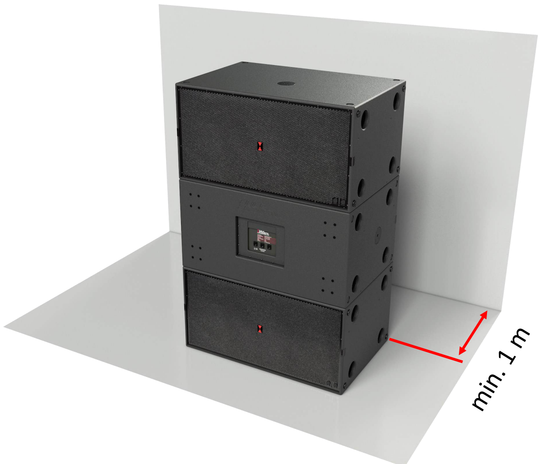
Distance between Stacks

A distance of at least **40 cm** must be maintained between the stacks. A smaller distance would impair their function.



Distance to Walls

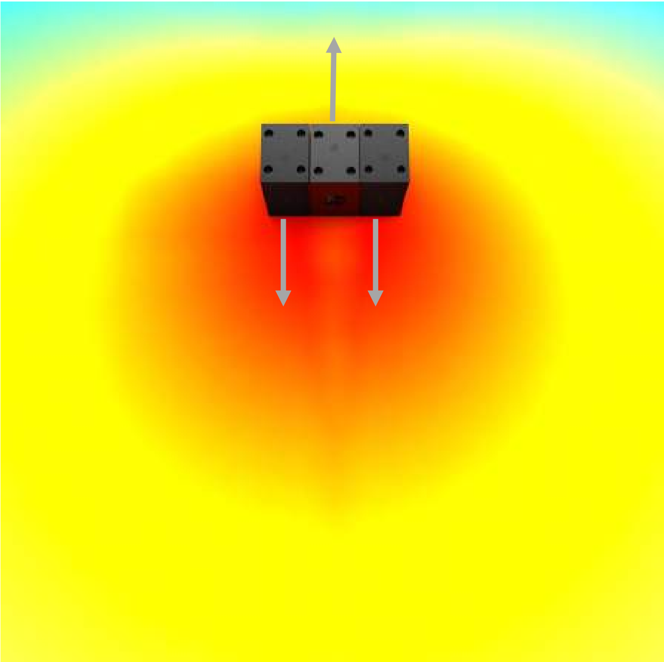
A distance of at least **1 m** must be maintained between the speakers and all walls. The distance to walls behind the stack is particularly important. If subwoofers need to be placed closer to a wall or rigid stage, directional subwoofer configurations should be avoided.



Configurations

Symmetrical Stacks for CSAG-Mode and CSAE-Mode

The presets are designed for symmetrical stacks consisting of three subwoofers in both CSAG- and CSAE-modes. The stacks can be configured in a vertical or horizontal array, or flown vertically.

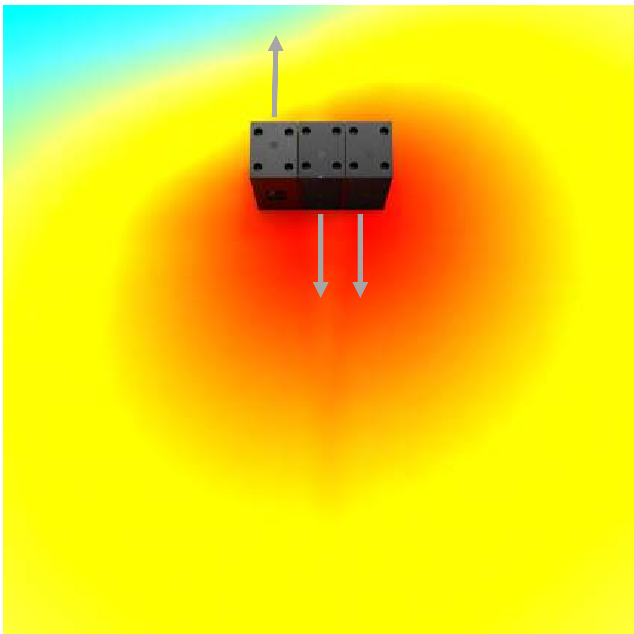


Asymmetrical Stacks

If an asymmetrical dispersion pattern is required, this can be achieved with asymmetrical stacks.

In asymmetrical configurations, the main radiation axis rotates toward the side where the forward-facing subwoofers are located.

In the example on the left, the main radiation axis rotates to the right, and in the example on the right (flying subwoofers), it rotates downwards. Asymmetrical stacks can be useful, for example, in a left/right setup next to the stage to reduce the sound energy radiating backwards towards the centre of the stage.



Stacks with 2 Subwoofers

It is also possible to build CSAG and CSAE stacks consisting of two subwoofers each. The lower subwoofer should face forward and the upper subwoofer should face backward.

For CSA**G** stacks consisting of two subwoofers, the rear-facing subwoofer should be **lowered by 3 dB** if the greatest possible cancellation directly behind the stack is desired.

If the CSA**G** stack is to be designed for high noise protection requirements (optimised for cancellation in the far field behind the stack), the level of the rear-facing subwoofer is not lowered.

Subwoofer (Line) Arrays

A few basic principles should be observed when configuring subwoofer (line) arrays.

To avoid minima in the area to be covered and maxima outside the area to be covered, a maximum distance between the subwoofers should be maintained so that they couple correctly with each other. The image on the right shows the dispersion pattern of an array with a significantly too large distance. Minima and maxima are clearly visible.

The maximum distance is relative to the wavelength. As a rule of thumb, a maximum distance s_{max} of half the wavelength of the highest frequency to be transmitted can be assumed.

$$s_{max} = \frac{\lambda_{min}}{2} = \frac{c}{2\,f_{max}}$$

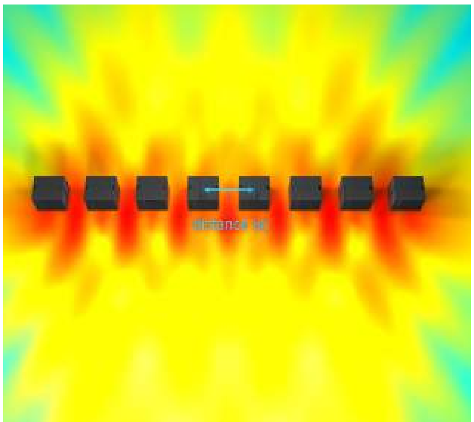
Please note: The speed of sound c depends on the temperature!

As an example, the maximum distance for a maximum transmission frequency of 120 Hz at a temperature of 20 °C is calculated here:

$$s_{max} = \frac{343\ \frac{m}{s}}{2 * 120\ Hz} = \frac{343\ \frac{m}{s}}{2 * 120\ \frac{1}{s}} = 1{,}4\ m$$

Since the maximum distance is determined, it is advisable to round off the result.

The distance determined refers to the distance between the centres of the sound sources. The distance between the centre of the grille and the centre of the grille should not exceed 1.4 m.



Distance between sound sources is significantly too large.

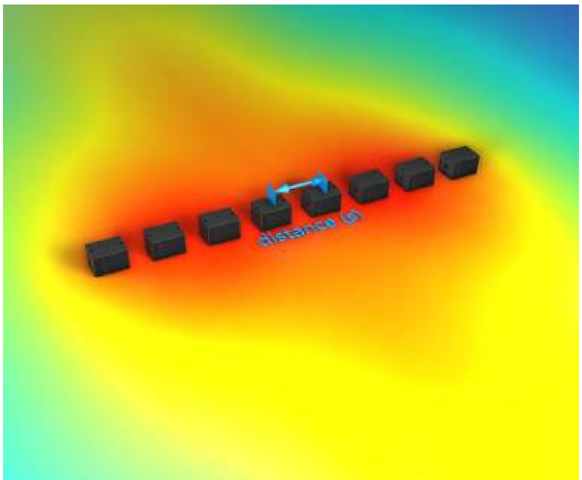
Temperature (°C)	Speed of sound (m/s)
0	331,5
10	337,5
20	343,5
30	349,3
40	354,9

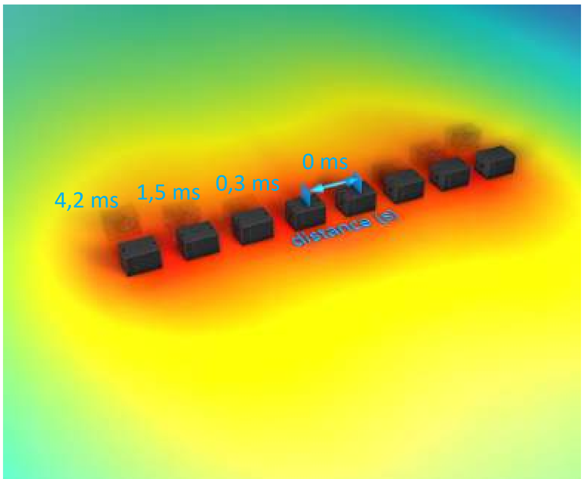
Speed of sound as a function of temperature.

The longer the subwoofer array, the narrower the array's dispersion. The decisive factor here is the ratio of array length to wavelength. This means that the dispersion pattern is frequency-dependent.

In terms of noise protection, a precise directionality can be advantageous. If less directionality is required for even sound coverage across the width, the array can be configured as an “sub-arc”. The arc does not have to be physically constructed. The arc can also be “virtually” reproduced by delaying individual subwoofers to make the horizontal dispersion pattern slightly wider again.

The following example shows a 10 m long array consisting of 8 subwoofers as a straight line (left) and as a “virtual” curved line (right). In the example on the right, the two middle subwoofers are not delayed, the others are delayed from the inside to the outside by 0.3 ms, 1.5 ms and 4.2 ms. This must be set on both sides, in the example from left to right: 4.2 ms, 1.5 ms, 0.3 ms, 0 ms, 0 ms, 0.3 ms, 1.5 ms, 4.2 ms.





Basics CSAG-Mode

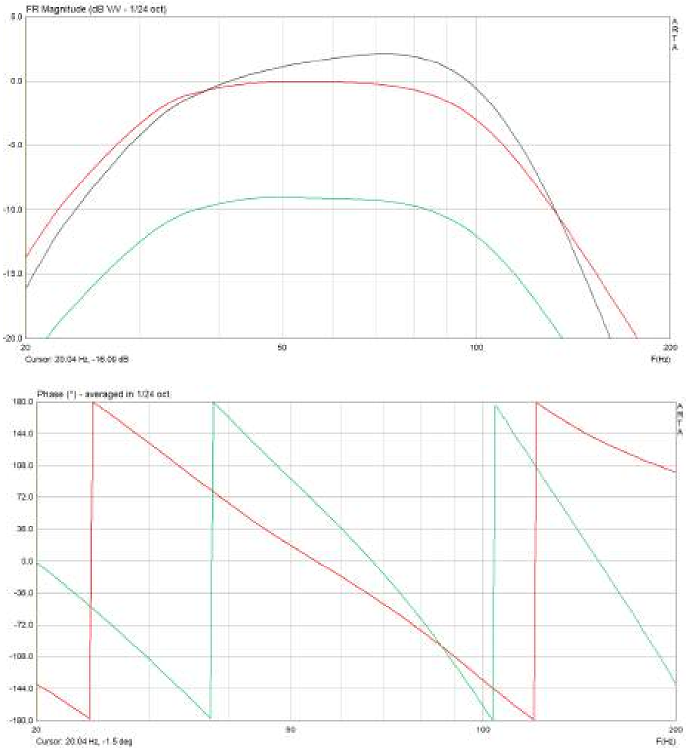
The directionality of CSAG-mode is achieved by using the rear subwoofer to cancel out the sound behind the CSAG stack through destructive interference. To do this, the signal for the rear subwoofer is delayed so that behind the CSAG stack, the signals from the front subwoofers are in phase with the signal from the rear subwoofer. To cancel out the sound signal behind the CSAG stack, the polarity of the rear subwoofer is reversed. It is important to note that the required delay is usually significantly greater than the depth of the subwoofers would suggest. It may also be the case that a simple delay is not sufficient to adjust the phase. Therefore, the required loudspeaker preset must be determined by measurement (everything is already set up in the Voice-Acoustic CSAG and CSAE presets). Furthermore, the level ratios must be adjusted. It should be noted here that the limiters must also be adjusted so that the directivity does not decrease at the maximum level.

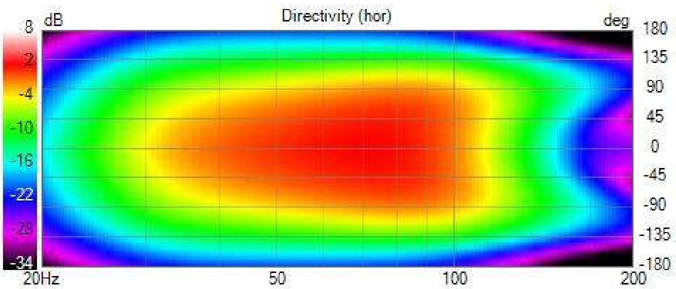
The CSAG-mode offers excellent rear damping but is weak at the front.

The figures on the right show the typical frequency responses of the front subwoofer (red) and rear subwoofer (green) of a CSAG stack, in magnitude (top) and phase (bottom).

The grey curve in the magnitude of the frequency response shows the sum of the front and rear subwoofers. It is clear that there is an area of constructive interference[1] and areas of destructive interference.

If only the magnitude of the frequency response is considered, it can be said that a CSAG stack consisting of **three** subwoofers has a higher sound pressure level than a conventional stack consisting of **two** subwoofers, but reduced low-end.





Typical dispersion pattern for CSAG-mode based on frequency.

The figure on the left shows the typical dispersion pattern of a CSAG stack. The advantage of the CSAG-mode can be seen here. The dispersion pattern is very good across the entire bandwidth and is therefore well suited for applications with high noise protection requirements.

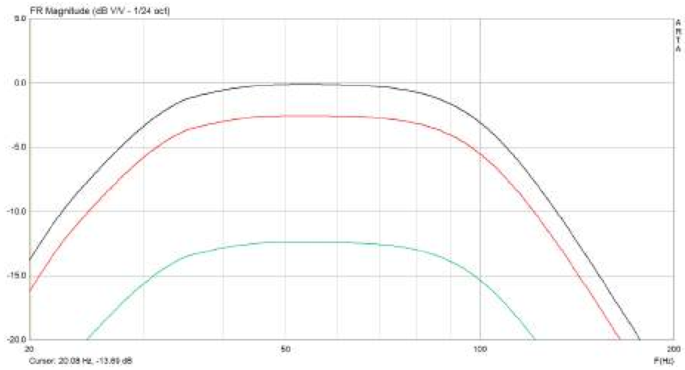
[1] see page 9

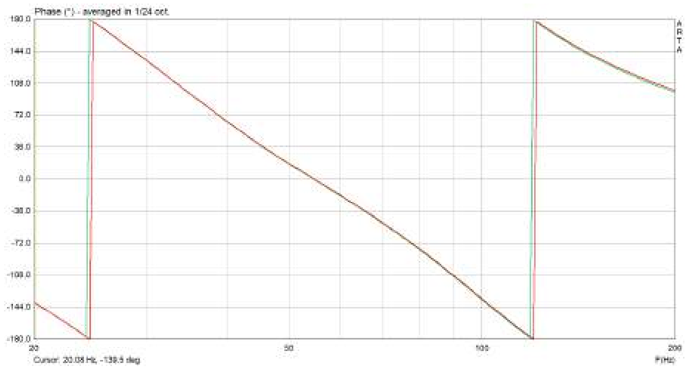
Basics CSAE-Mode

When referring to an end-fire array, this usually means an arrangement of subwoofers in several rows behind each other. All rows are delayed relative to the sound signal of the rear row. This causes the rows to add up towards the front. Towards the rear, there are frequency-dependent cancellations due to the time delay of the sound signals.

A much more space-saving and easier-to-use setup is a stack with two front subwoofers and one rear subwoofer, as in CSAG-mode. Here, too, the front subwoofers are delayed relative to the sound signal from the rear subwoofer. The delay required for this setup is usually much greater than the depth of the subwoofers would suggest. It may also happen that a simple delay is not sufficient to adjust the phase.

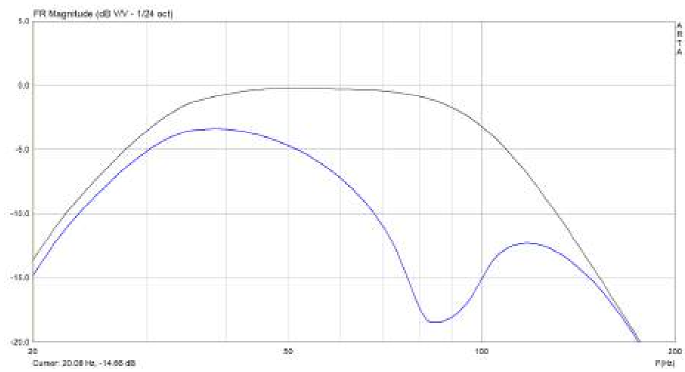
In front of the CSAE stack the signals are added in phase. This ensures that the sound quality at the front is unaffected.. However, compared to a conventional stack of three forward-facing subwoofers, the CSAE stack is slightly quieter. It should also be noted that the system's overall delay increases (our loudspeaker presets are developed so that the tops for all subwoofers in CSAE mode must be delayed by **4 ms / 1.38 m**).



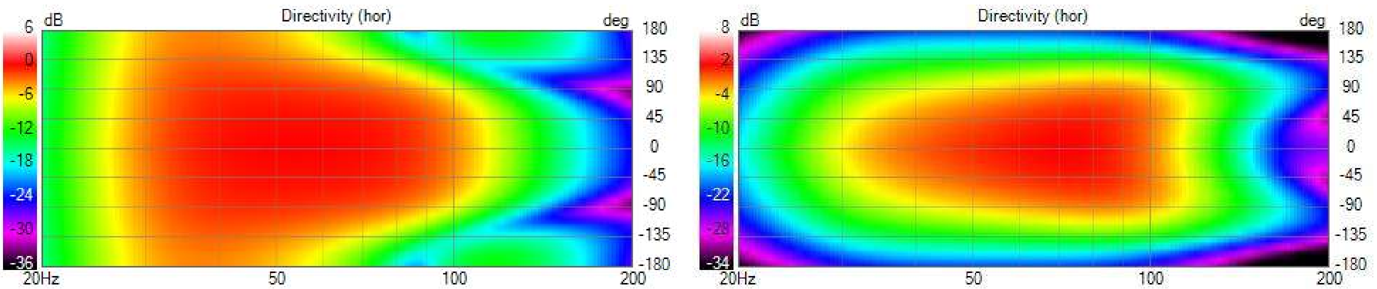


The directivity of the CSAE stack is significantly frequency-dependent. The figure on the right shows the amount of the frequency response of a CSAE stack in grey for the front and in blue for the rear. Significant directivity is only achieved in a narrow frequency range. This depends on the actual time delay between the front and rear subwoofers (which does not only depend on the depth of the subwoofers).

In simple terms, larger and deeper subwoofers achieve better directivity than smaller ones.



The figures below show the typical dispersion characteristics of a CSAE stack (left) and a CSAG stack (right). It is clear that the dispersion behaviour of the CSAE-mode is significantly more dependent on frequency than that of the CSAG-mode.



The typical dispersion patterns of CSAE-mode (left) and CSAG-mode (right) are shown based on frequency

Top-Sub Alignment

In most cases, the frequency range of PA systems is extended downwards with subwoofers. These are often placed separately from the tops. There are a few basic principles to keep in mind here, which are described below.

Our presets are designed so that tops and subs play together correctly in time when placed grille to grille (see illustration on the right).

If physically separated setups are used, the resulting time differences must be corrected by using electronic delay.

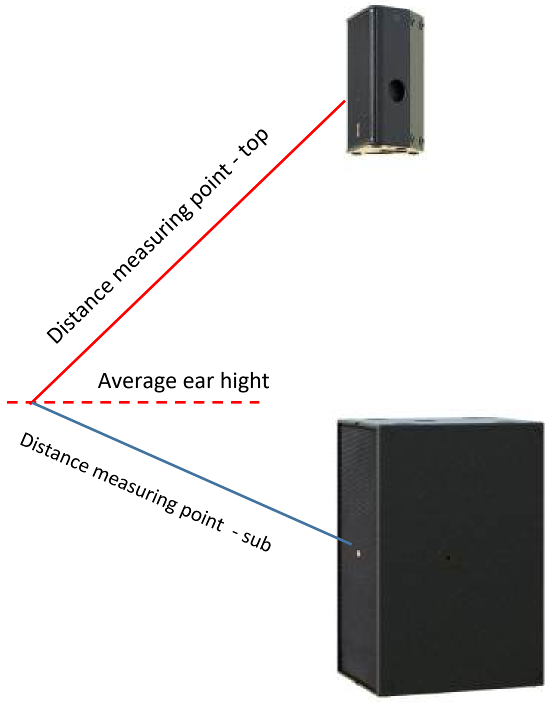
Using the front grille as a reference surface, it is possible in many cases to perform this time delay correction without an acoustic measurement system, using only a laser distance measurement device.

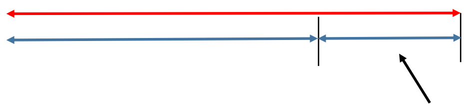
To do this, the distance to the top and subwoofer can be measured and the difference in distances calculated. The speaker that is less far away can be delayed according to the difference in distance. The required delay can be set directly as a distance (m) in the VADAS or HDSP system power amplifiers. Conversion to a time unit (ms) is not necessary.

For larger subwoofer stacks, it should be noted that the times shift, which is why the use of an acoustic measurement system is recommended.

If the top parts are flown **up to approx. 3.5 m in height**, the choice of measuring point is not critical. The measuring point should be selected approximately at the expected ear height in the listener area. The distance to the top unit and to the subwoofer is measured and the difference is calculated. The closer loudspeaker is then delayed by this difference. The quality of the measurement setup is shown in the figure on the right.

If the top sections are flown higher or complex surfaces are to be covered, this simple procedure is not sufficient and a suitably qualified person with measuring equipment should be consulted.





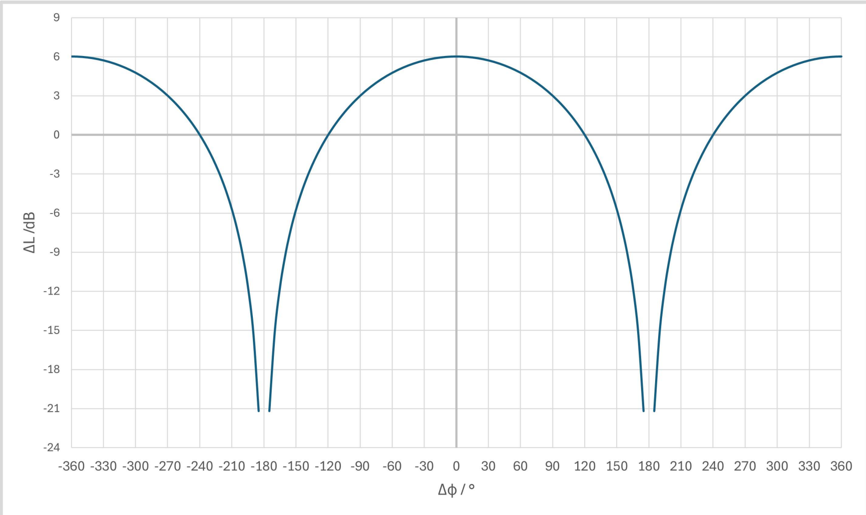
Note:

Interference

Interference occurs when several waves overlap. The overlap occurs without interference, i.e. the waves do not influence each other (the superposition principle applies).

A distinction is made between constructive and destructive interference. Constructive interference results in an increase in the resulting wave, while destructive interference results in cancellation. The figure below shows the sum of two sound events of the same frequency and amplitude dependent on the phase angle.

Area of cancellation and addition



professional german loudspeaker systems

Impressum

All information in this manual regarding the properties of the products described herein and the relevant safety regulations is based on the information available at the time of printing. Technical specifications, dimensions, weight and properties are not guaranteed characteristics.The manufacturer expressly reserves the right to make changes and modifications within the scope of the statutory provisions, with the aim of improving product properties.This manual and all other information necessary for the safe use of the system must be made available to all persons using the system during assembly, disassembly and operation.The system must not be assembled or used unless this manual has been read, understood, and kept on site at all times.We welcome your suggestions and ideas for improvingthis manual.

SRV Distribution - Voice-Acoustic
Brocksfeld 3
D-27313 Dörverden

Fon.: + 49 (0) 4234 942 777

Request@Voice-Acoustic.de
www.Voice-Acoustic.de