TI 350
Q-Series system design and Q-Calc (1.2EN)

d&b audiotechnik

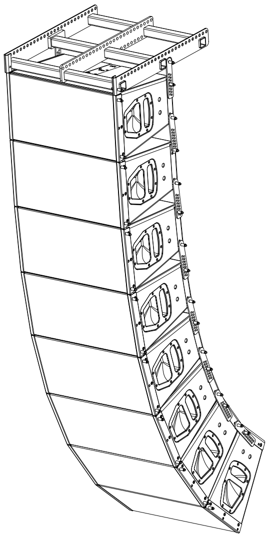
1. Introduction

This Technical Information paper will explain the procedure for designing and tuning Q-Series line array systems in a given venue using the d&b Q-Calc array calculators. It assumes that the Q-Series cabinets are driven by d&b D12 amplifiers.

WARNING!
Before setting up a system read the Q-Series manuals and safety instructions.

2. The Q-Series line array

The Q1 is a compact and lightweight line array cabinet providing a 75° constant directivity coverage in the horizontal plane down to 400 Hz. The system can be used from very small configurations of two cabinets per array up to a maximum of twenty cabinets per array for larger venues.



Q1 cabinets have a very low height of only 30 cm (1 ft) and when combined in arrays its accurate wavefront covers up to 14° vertically per cabinet, and couples coherently up to 12 kHz when configured in a straight (0° splay) long throw section. The Q1 covers the frequency range from 60 Hz to 17 kHz.

The Q7 and Q10 cabinets are mechanically and acoustically compatible loudspeakers with 75° x 40° and 110° x 40° spherical dispersion patterns which can be used as a downfill (Q7) or nearfill extension with Q1 arrays.

Smaller configurations of Q1 cabinets can also be used ground stacked, supported by Q-SUB cabinets. The most even energy distribution in the audience area will however be achieved with a flown array.

3. Number of cabinets required

The number of Q1 cabinets to be used in an application depends on the desired level, the distances and the directivity requirements in the particular venue. Using the d&b Q-Calc array calculator will define whether the system will be able to fullfill the requirements.

Depending on the program material and the desired level additional Q-SUB and / or B2-SUB subwoofer systems will be necessary to extend the systems bandwidth and headroom. The number of Q-SUBs needed per Q1 cabinet for serious full range program will decrease with the size of the system. For small set ups a 1:1 ratio is recommended for example four Q-SUBs to four Q1s, while larger systems will work with a 2:3 ratio for example eight Q-SUBs to twelve Q1s. Please note that CSA set ups require a multiple of three Q-SUB cabinets.

4. Subwoofer set up

Subwoofers are operated most efficiently when stacked on the ground. For cleanest sound and coverage we recommend arranging subwoofers in a CSA configuration as described in d&b TI 330 Cardioid Subwoofer Array which is available for download from the d&b audiotechnik website at www.dbaudio.com.

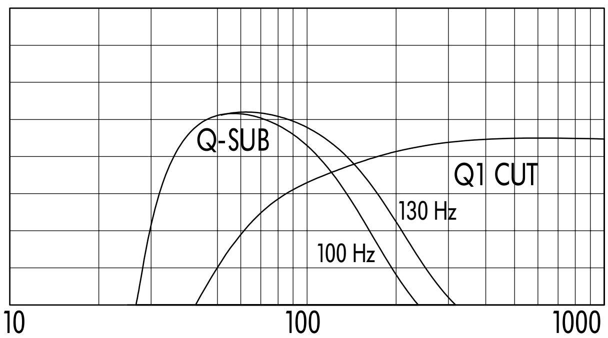
When used with additional subwoofers the Q1 systems should be operated in CUT mode to gain maximum headroom at low frequencies.

4.1 Q-SUB (40 – 100 / 130 Hz)

Q-SUB cabinets can be used ground stacked or integrated into the flown array, either on top of a Q1 array or flown as a separate column.

Flown Q-SUBs will create a different level distribution in the audience area than ground stacked ones. In particular the area at the very front, below the arrays will have much less low frequency energy when subwoofers are included in the array. This can be very useful in applications that do not require high levels of low frequency energy at the front, however for an event requiring a loud stage level additional ground stacked subwoofers may be necessary.

For Q1 arrays consisting of three or more cabinets we recommend the use of the 100 Hz setting for the Q-SUB systems. Smaller Q1 arrays providing less coupling at low frequencies may benefit from the higher crossover frequency of the standard mode of the Q-SUBs (130 Hz).



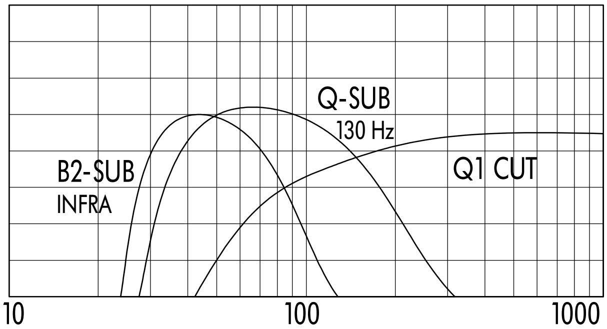
Q1/Q-SUB crossover set up

Compared to a standard Q-SUB configuration a CSA set up produces slightly less level above 70 Hz, so it may be advantageous to use the standard (130 Hz) controller setting.

4.2 B2-SUB (32 – 68 / 100 Hz)

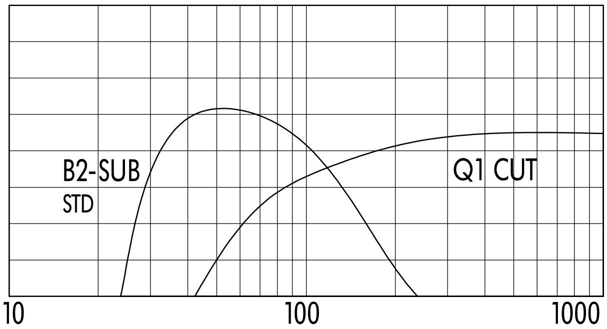
B2-SUB cabinets can be used to supplement a Q1 system in different ways.

If the system is equipped with a sufficient number of Q-SUB cabinets, B2-SUBs can be used to extend its bandwidth to below 40 Hz. Driven by A1 or D12 amplifiers set to INFRA mode one B2-SUB will supplement up to four Q-SUB cabinets. This combination will achieve its maximum headroom when the Q-SUBs are operated in the 130 Hz mode. If for audio reasons the lower crossover frequency to the Q1s is desired you may also reduce the gain of the Q-SUB controllers. Decreasing the gain by 2.5 dB will create the same downward shift to the upper slope as switching to the 100 Hz setting, but with less low frequency boost.



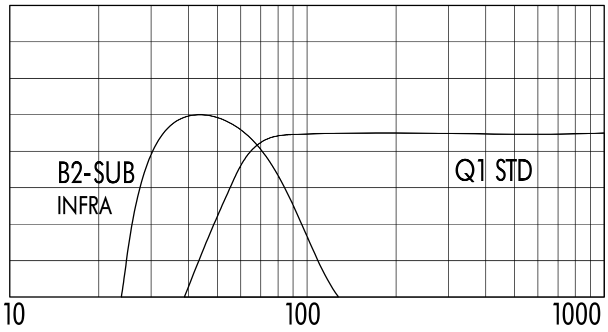
Q1 / Q-SUB / B2-SUB crossover set up

B2 subwoofers can also be used as an alternative to ground stacked Q-SUBs. In this case B2-SUB cabinets are operated in standard mode with a crossover frequency of 100 Hz (only possible using D12 amplifiers from firmware version V1.02, the standard mode of A1 / B2 controllers only applies to d&b C7 / F2 systems). One B2-SUB will replace two Q-SUB cabinets as well as extending the system bandwidth to below 40 Hz.



Q1 / B2-SUB crossover set up

B2-SUB cabinets in INFRA mode can be used to extend the bandwidth of a Q1 line array operated in full range mode, without Q-SUBs. As this application does not expand the headroom of the Q1 array it is only useful when medium levels but very low frequencies are required for example for special effects.



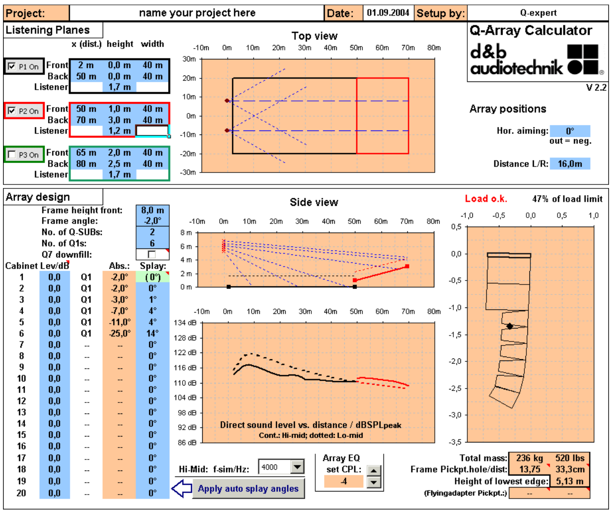
Q1 / B2-SUB crossover set up, full range

5. Q-Calc array calculator

For both acoustical and safety reasons Q1 arrays should normally be designed using the d&b Q-Calc array calculator simulation tool for Microsoft® Excel.

Q-Calc uses a sophisticated mathematical model synthesizing each cabinet's wave front by an array of narrow spaced point sources. Using complex data (phase information) it calculates the level distribution in multiple frequency bands on up to three different audience areas. At the same time Q-Calc monitors the physical parameters of the array including the actual mechanical forces within the rigging components and displays a warning if an overload occurs.

Q-Calc is available in two versions: Q-CalcStack for ground stacked Q1 / Q-SUB systems and Q-CalcRig for designing flown set ups. In the following chapter the operation of Q-CalcRig will be explained.



Q-CalcRig array calculator

5.1 Microsoft® Excel set up

Q-Calc contains macros, therefore macros must be enabled. Macro security level can be set to "medium" (recommended: Excel asks if macros shall be enabled when loading a file which contains macros; "Enable Macros" must be clicked) or "low" (not recommended: Excel automatically accepts all macros).

5.2 Data input

Only the highlighted (blue) cells and the project header accept data input. All other cells are results and cannot be edited. Cells marked with a small (red) triangle in the upper right corner contain additional help texts, to be accessed with the mouse pointer.

Splay:
(0°)

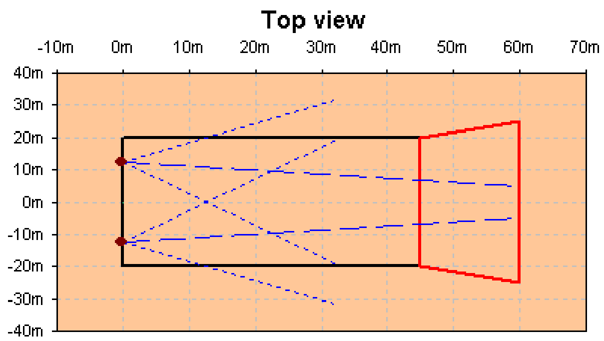
5.3 Listening planes

		x (dist.)	height	width
☑ P1 On	Front	0 m	0,0 m	40 m
	Back	45 m	0,0 m	40 m
	Listener		1,7 m	
☑ P2 On	Front	45 m	1,0 m	40 m
	Back	60 m	3,0 m	50 m
	Listener		1,2 m	
☐ P3 On	Front	65 m	2,0 m	40 m
	Back	80 m	2,5 m	40 m
	Listener		1,7 m	

Input the coordinates of the listening planes and the typical height of the listeners ear. Up to 3 planes can be used. Each plane is activated by its on / off tick.

5.4 Top view

The top view shows the active listening planes and the uppermost cabinet of each array with its main axis and coverage area (-6 dB isobars).



5.5 Array positions

Hor. aiming: 7°
out = neg.

Distance L/R: 25,0m

Hor. aiming:
Horizontal aiming of the arrays (positive value: rotated inwards, negative value: outwards).

Distance L/R:
This allows the distance between the arrays to be defined. When set to zero only a single array will be displayed.

The width of the planes and the array positions are only used to show the horizontal coverage in the top view window. There is no effect on the calculation of the SPL.

5.6 Array design

A vertical array of Q1 cabinets produces a precisely shaped wave front following the mechanical arrangement of the cabinets. The cut off at the upper and lower limits of the vertical dispersion of a Q1 column is very sharp, and therefore precise aiming is absolutely essential to address the desired audience area.

The first parameter to set is the Flying frame angle and height. For best results the top cabinet of the column should aim at the farthest point in the audience area. Aiming the Flying frame up to 2° above this point sometimes gives a smoother coverage. Check the SPL plot for the effect but at the same time consider a possible increase of reflections from the rear walls.

Frame height front:	7,0 m
Frame angle:	-2,3°
No. of Q-SUBs:	0
No. of Q1s:	8
Q7 downfill:	☐

Frame height front:
Height above ground of the front edge of the Flying frame.

Frame angle:
Vertical aiming of the entire array.

No. of Q-SUBs:
Number of Q-SUB cabinets used in the array. Q-SUBs will always be inserted at the top of the column.

No. of Q1s:
Number of Q1 cabinets used in the array.

Q7 downfill:
A Q7 loudspeaker (horizontally mounted with rotated horn) can be inserted at the very bottom of the array. The maximum splay of 14° is used here. Compared to a Q1 used in the same position this set up gains about 10° more coverage to the front for high frequencies. Please note that the mid and low frequency coverage of the array will not be extended by using a Q7 as the lowest cabinet.

Q7 cabinets have to be driven by separate amplifier channels in Q7 configuration.

Acoustically a ground stacked front fill system for example Q7s or Q10s supported by Q-SUBs is preferable to cover the very front of the audience area.

5.7 Splay angles

The coverage and level distribution in the audience areas is adjusted using the splay angle between the cabinets. The first entry in the column is the angle between Flying frame and first cabinet which is always set to 0°. On the left side of the splay column the absolute vertical aiming of each cabinet is displayed.

Cabinet	Lev/dB		Abs.:	Splay:
1	0,0	Q1	-2,3°	(0°)
2	0,0	Q1	-3,3°	1°
3	0,0	Q1	-5,3°	2°
4	0,0	Q1	-7,3°	2°
5	0,0	Q1	-9,3°	2°
6	0,0	Q1	-13,3°	4°
7	0,0	Q1	-22,3°	9°
8	0,0	Q1	-36,3°	14°

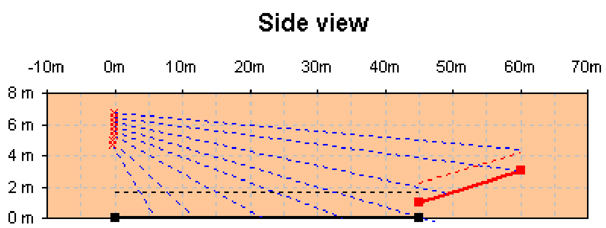
The vertical coverage angle of a single cabinet is 15° and this defines the maximum vertical splay angle of 14° between adjacent cabinets in a column. This dispersion angle is achieved above approximately 5 kHz, while lower frequencies will disperse into a wider area creating an overlap of the coverage patterns between the single cabinets. Therefore directivity and the level of lower frequencies increase with every cabinet added to the column.

Decreasing the splay to angles smaller than 10° will also create an overlap of the coverage patterns above 5 kHz resulting in increased high frequency output. This effect is used when covering remote audience areas where additional high frequency energy is needed to maintain speech intelligibility in a reverberant venue, and to compensate for the HF absorption of air which increases with distance.

Usually the distances to the audience that an array has to cover decrease from the top to the bottom of a column, consequently it is desirable to gradually increase the vertical splay angles between adjacent cabinets, for example 1°, 3°, 10° from the top to the bottom of a 4-deep column.

5.8 Side view

The side view shows a cross section through the active listening planes with the listener ear level and one of the arrays. Each dashed beam marks the centre axis of one cabinet.



5.9 Using the "Apply auto splay angles"

You may use the "Apply auto splay angles" function to get start values which should later be optimized manually to achieve the desired SPL distribution.

Apply auto splay angles

The algorithm creates a J-shaped array with cabinet aiming points equally spaced along the listening planes, the Flying frame angle (= top cabinet) is aimed at the farthest listening point.

5.10 SPL plot

The SPL plot shows the direct sound level vs. distance for two frequency bands and for all active listening planes. The displayed figures represent the peak SPL, the averaged continuous level will be at least 6 dB lower.

The dotted curve represents the lower range around 250 Hz where the dispersion is defined by the overall array curving, not by the particular aiming of single cabinets. The continuous curve shows the high / mid range level distribution, selectable in octave bands from 1000 Hz to 8000 Hz.

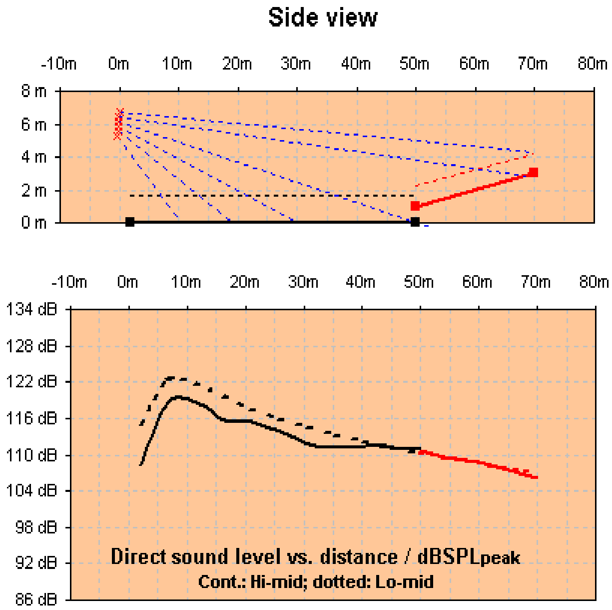
Hi-Mid: f-sim/Hz: 4000

The higher the frequency the more the coverage is defined by the individual aiming of each cabinet. Using 4 kHz for the high / mid curve is a good compromise, giving enough directivity information while not confusing too much with rippled curves and the HF absorption of air (see also 7.1. HF level). Try to match as closely as possible the characteristics of the curves by modifying the splay angle settings.

Increasing the splay between two cabinets will reduce the high / mid level in their target area, decreasing the splay will increase the level. As the plot only displays direct sound, you have to keep in mind that reverberant sound will change the balance between low and high frequencies, typically towards the lower frequencies. Allow a relative increase (not an absolute increase) of higher frequencies towards larger distances to maintain good intelligibility.

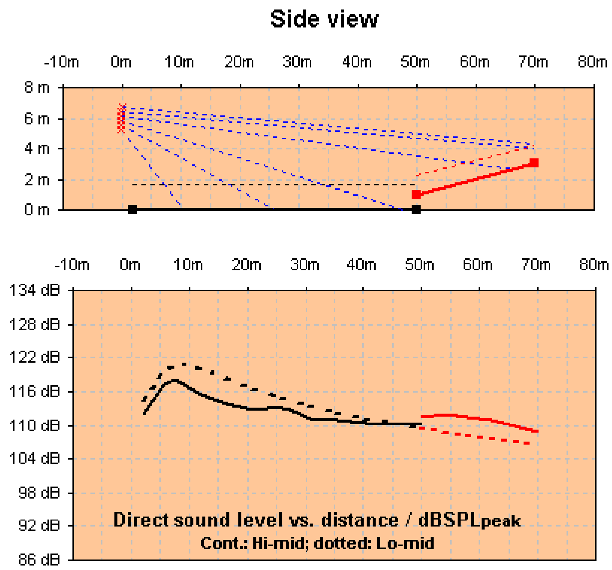
The following two examples show different splay configurations and the effect on the SPL distribution for a 6-deep array in the same venue.

In the first set up the plots for low / mid and high / mid SPL (4 kHz band) are very similar. The high/mid directivity of the system is not very high in order to match the level drop of the lower frequencies. As a consequence the tonal balance of the systems direct sound will be very consistent over distance. This set up will work in a room with low reverberation and for program material where the tonal balance is more important than an optimum intelligibility and level distribution in the far field.



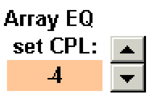
6-deep Q1 set up, medium directivity

In the second example the system is tuned the opposite way in order to adapt it to a critical acoustical environment. More cabinets are covering the far field to reduce the drop in level over distance at high and mid frequencies. The higher direct sound level at the back of the room will compensate for the reverberant field and increase the speech intelligibility.



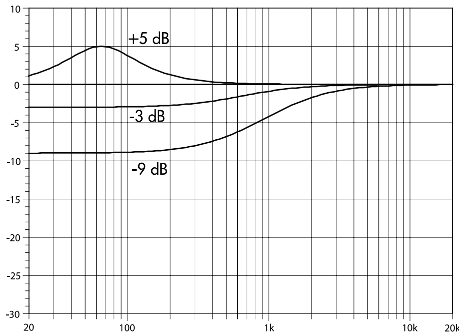
6-deep Q1 set up, high directivity

5.11 Array EQ / CPL



Two to three Q1 cabinets arrayed vertically with up to 15° total splay angle produce a flat frequency response. Longer columns with more total splay will boost low and low / mid frequencies. The CPL function of the controller compensates for these effects. While setting the splay angles the Array EQ "Coupling" (CPL) parameter can be set to a useful attenuation (dB) of lower frequencies to achieve a balanced sound. The low / mid curve of the SPL plot will shift accordingly.

This parameter is available in the d&b D12 controller set ups for Q1, Q7 and Q10 and should also be set there (CPL: 0...–9 dB). All the D12 controller channels in one array have to be set to the same CPL value.



Frequency response correction of the D12 CPL circuit

Positive CPL values (max. +5 dB, not supported by Q-Calc) will produce a low frequency boost. This is useful when small arrays without additional subwoofers are used for full range coverage. Positive CPL will reduce the headroom of the system.

The CPL function in the E-PAC can not be modified. It attenuates by 3 dB.

5.12 Level adjustment (Lev/dB)

After having set the splay angles you may still find a significant increase in level very close to the array. It can be adjusted by decreasing the level of the lower cabinets of the array. When applying this to Q-Calc, consider that usually several cabinets are linked to the same amplifier channel, so set the levels equally for all cabinets which will be connected in parallel.

For the simulation in Q-Calc you should only apply attenuations (negative values). Positive values will lead to SPL figures in the plot which might not be realistic.

Keep in mind that for a lot of applications a certain increase in level towards the front is expected or even required, in particular with ground stacked subwoofers.

5.13 Load parameters and Pick point

Total mass:	82 kg	181 lbs
Frame Pickpt.hole/dist:	11,00	26,1cm
Height of lowest edge:		4,02 m
(Flyingadapter Pickpt.:)	4,0	24,9cm

Total mass:
The calculated weight of the array including all rigging components.

Flying frame Pickpt.hole/dist:
When you want to suspend the array from a single pick point, these values indicate where the Flying frame has to be attached to arrive at the desired vertical aiming of the array. It displays the closest hole of the frame's hole grid, counted from the front of the frame, and the exact position as a distance from the front of the frame´s centre beam.

Half holes can be set using the Z5155 Q Hoist connector chain with two shackles located in the holes adjacent to the given pick point position. Using the Z5160 Q Load adapter a resolution of 1/4 hole is provided.

If the calculated pick point is beyond the frame an error message will be displayed:

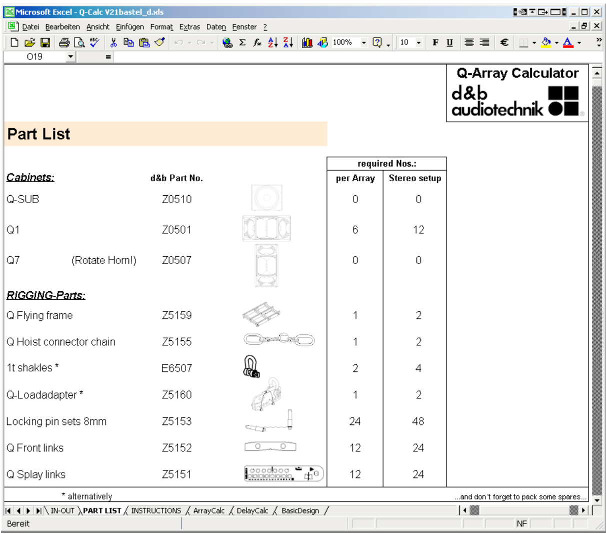
Pickpoint outside frame - setup not possible!

Height of lowest edge:
Height above the ground of the lowest edge of the array.

Flying adapter Pickpt.:
Q1 arrays up to 3-deep may be suspended with the Z5156 Q Flying adapter. The respective hole position from the front is displayed when up to three Q1s are selected.

5.14 Part list

According to the designed array Q-Calc will generate a parts list including all cabinets and rigging components that are needed for both the single column and a left / right set up.


Microsoft Excel - Q-Calc V21bastel_d.xls

Q-Array Calculator
d&b audiotechnik

Part List

Cabinets:	d&b Part No.	required Nos.: per Array	required Nos.: Stereo setup
Q-SUB	Z0510	0	0
Q1	Z0501	6	12
Q7 (Rotate Horn!)	Z0507	0	0
RIGGING-Parts:			
Q Flying frame	Z5159	1	2
Q Hoist connector chain	Z5155	1	2
1t shakles *	E6507	2	4
Q-Loadadapter *	Z5160	1	2
Locking pin sets 8mm	Z5153	24	48
Q Front links	Z5152	12	24
Q Splay links	Z5151	12	24

* alternatively

...and don´t forget to pack some spares...

Q-Calc Parts list

5.15 Load condition

The array side view shows the mechanical set up of the cabinets including the centre of gravity of the whole array.

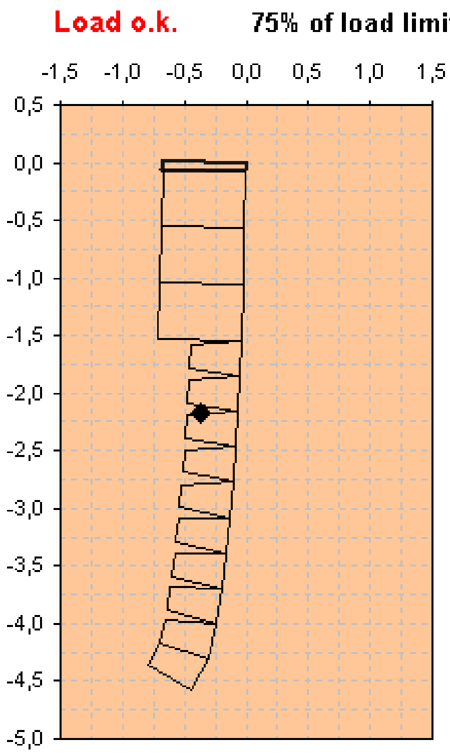
If the load conditions are within the load limits the following message will be displayed:

Load o.k. **59% of load limit**

If the load limits are exceeded the following message will displayed:

OVERLOAD! **112% of load limit**

WARNING!
Never set up an array which exceeds the load limits. Reduce the number of cabinets or the total splay angle until the load conditions are within limits. Otherwise there is a risk of damage to persons and / or materials !



6. Horizontal array of Q1 cabinets

The horizontal angle between adjacent Q1 line arrays can be set to between 40° and 60°. The most even energy distribution is achieved with 50°. Smaller horizontal angles between the columns will give a smaller horizontal coverage area, but will produce higher sound pressure on the centre axis and increased comb filter effects between the arrays.

The configuration should be thoroughly adapted to the actual room acoustics and requirements. In order to keep diffuse sound low, the total coverage angle should only be as wide as necessary to cover the audience area.

The smoothest coverage will be achieved if both columns of a horizontal array have identical vertical set ups. If the columns need to be considerably different in length or vertical aiming a distance of at least 3 m (10 ft) between their lifting points will reduce interference effects.

7. System tuning

Besides the correct setting of CUT and CPL functions as described before additional tuning may be necessary. The most convenient way to finalize the system tuning is using the d&b Remote network with the ROPE C software.

7.1 D12 Q1 and Q1 Line configuration

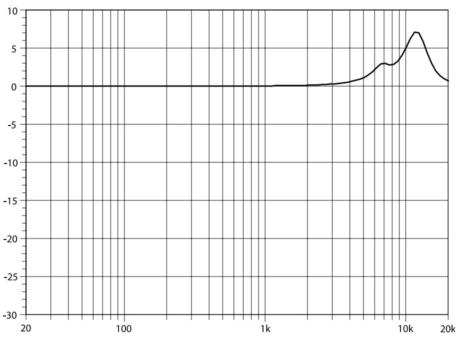
The D12 amplifier provides two configurations for Q1 cabinets (from D12 firmware V2.10). Which to select depends on the curvature of the array. Straight array sections (small splay angles) considerably extend the acoustical near field of the sources. These cabinets need a different tonal balance than cabinets used in curved array sections. Therefore within a typical Q1 array both amplifier configurations may be used.

The standard configuration is used for Q1 loudspeakers when used in small arrays up to 4 cabinets and in curved sections of larger arrays. The "Line" configuration is used for groups of four or more Q1 loudspeakers which are coupled to a straight long throw array section where the splay angles to adjacent cabinets are 0°,1° or 2°. Compared to the standard configuration the mid/-high range is reduced to compensate for the extended near field. The transition from "Q1 Line" to the "Q1" configuration within the array is made according to the splay progression but may allow for certain deviations due to the paired wiring of the cabinets.

7.2 HF level

The transmission of high frequency energy through air suffers from sound absorption effects, over distance the increase of this effect is linear. As this effect also depends on air temperature and humidity it is not taken into account in Q-Calc. If necessary it can be compensated for by increasing the HF level of the particular cabinets which cover the far field by selecting HFC at the respective amplifier channels.

Keep this in mind when wiring the cabinets in a column. All cabinets linked to one amplifier output will be operated with the same D12 controller setting.



Frequency response correction of the D12 HFC circuit

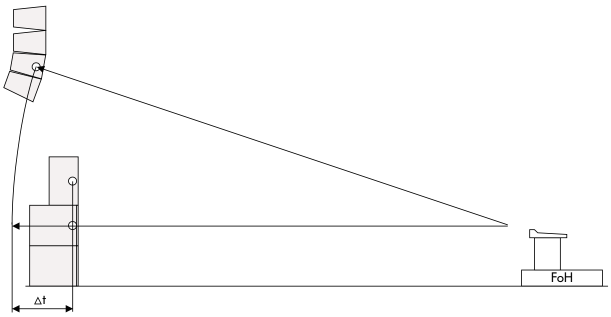
7.3 Time alignment

Within a line array column it is absolutely essential to maintain a perfect time alignment. Otherwise the whole principle of creating a coherent wave front will fail. Therefore all amplifiers used to drive one column must be fed from the same input signal. Should an additional delay be necessary the setting must be identical for all amplifier channels used in the array.

For a correct time alignment ground stacked subwoofers should be placed directly below the array. If this is not possible the delay function in the D12 amplifier channels should be used to correct the timing in the front-of-house direction. In the following example the subwoofer amplifiers have to be set to a delay time of Δt, equivalent to the physical offset Δx divided by the speed of sound (343 m / s or 1126 ft / s).

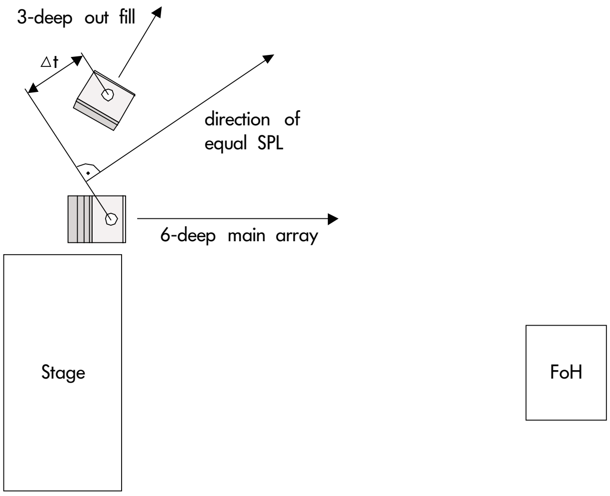
$$\Delta t = \frac{\Delta x}{v_{sound}}$$

If nearfill loudspeakers are used on top of the subwoofers the respective amplifier channels have also to be set to this delay time. This is particularly important to maintain a correct source imaging in respect to the main array.



Time alignment of ground stacked cabinets

If more than one column of Q1s are used per side the array should be time aligned towards the direction where both arrays produce equal level.



Time alignment of a horizontal array

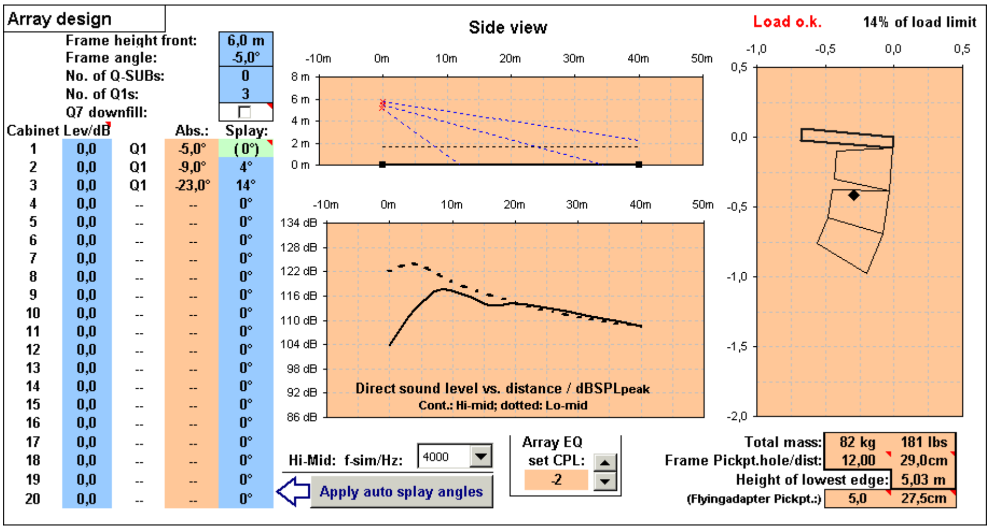
7.4 Equalization

If additional equalization of the system is required, use the d&b D12 amplifier's 4-band fully parametric equalizer for each channel. It is important when applying the equalization that all channels within one line array are set identically. Using the d&b Remote network and the ROPE C software the amplifier channels and their equalizers can be operated in user defined groups.

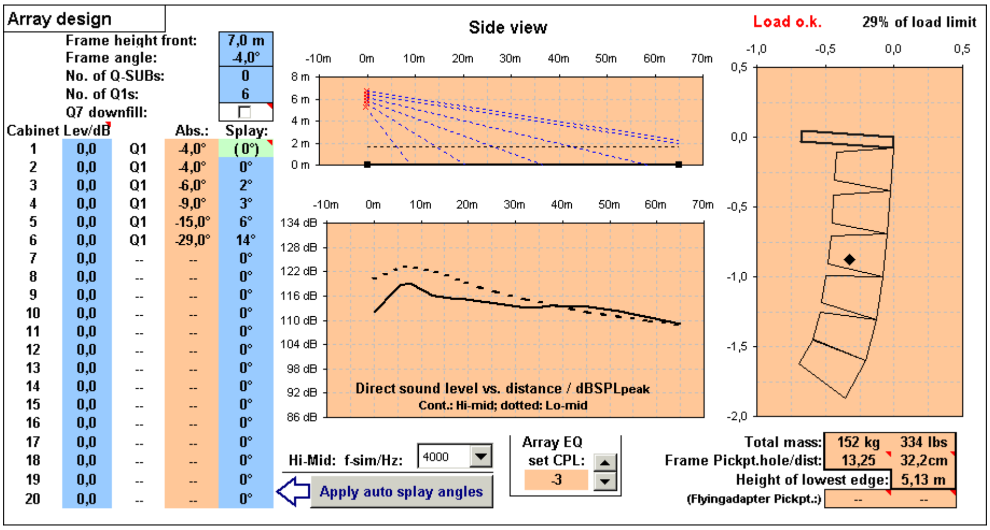
Using the D12 parametric equalizer for the system EQ provides the sound engineer with a flat FoH EQ for his personal sound design.

8. Q-CalcRig example set ups

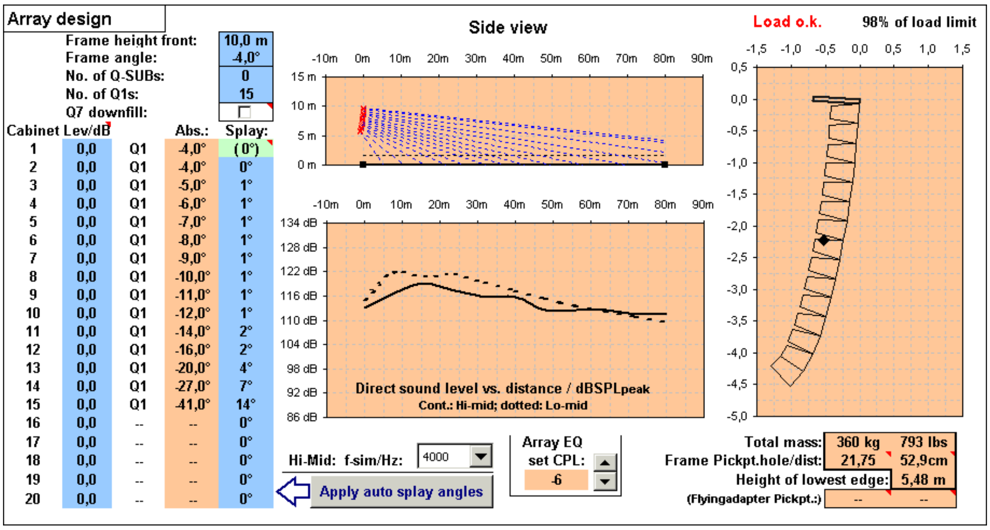
The following pages show a selection of Q1 line array set ups for different array sizes and locations.



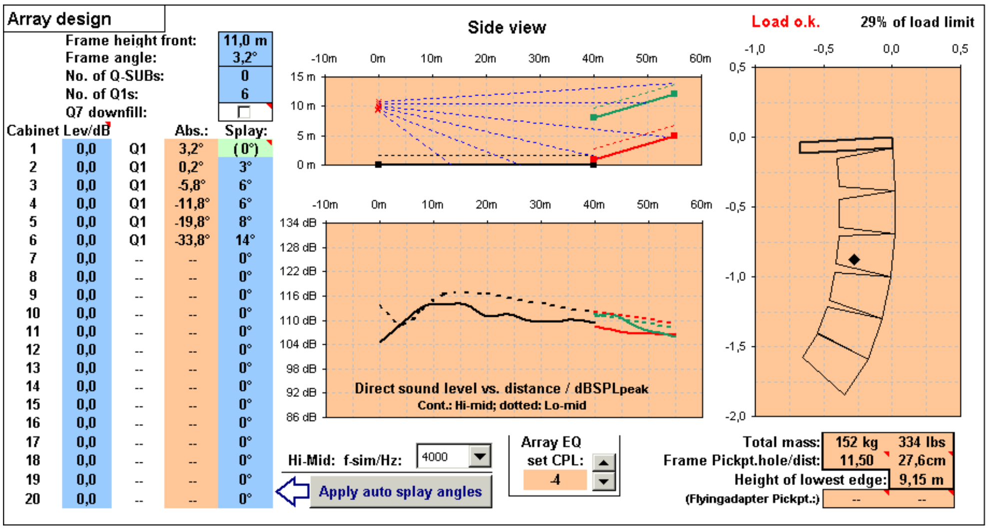
Example 1: three Q1s flat field



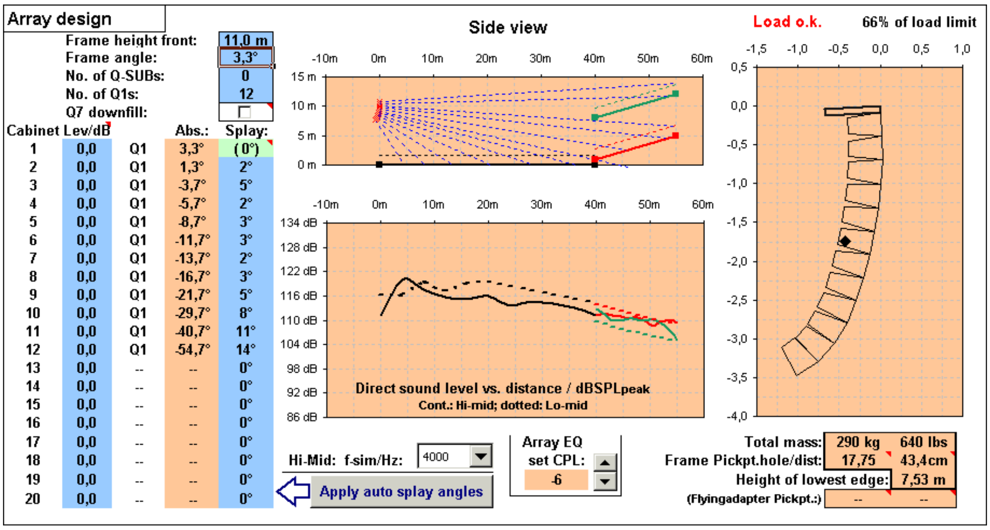
Example 2: six Q1s flat field



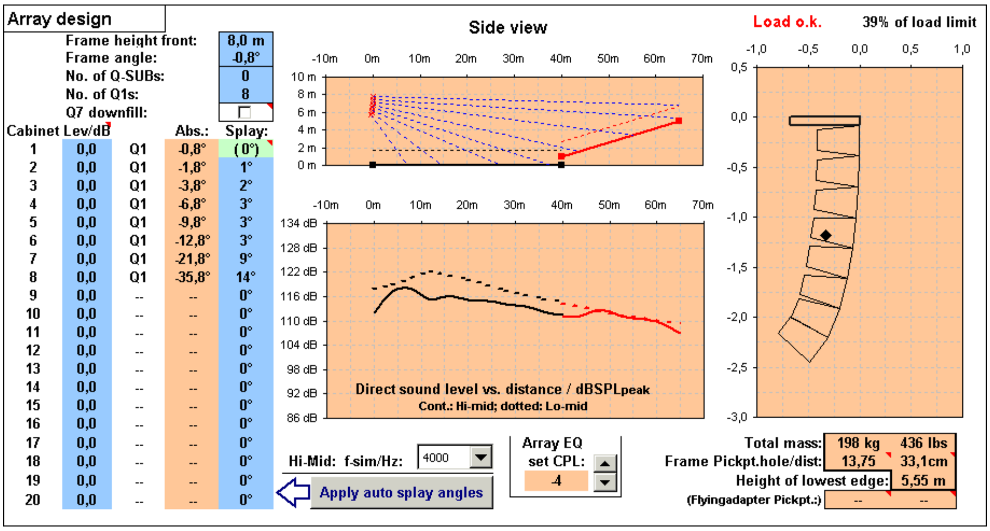
Example 3: fifteen Q1s flat field



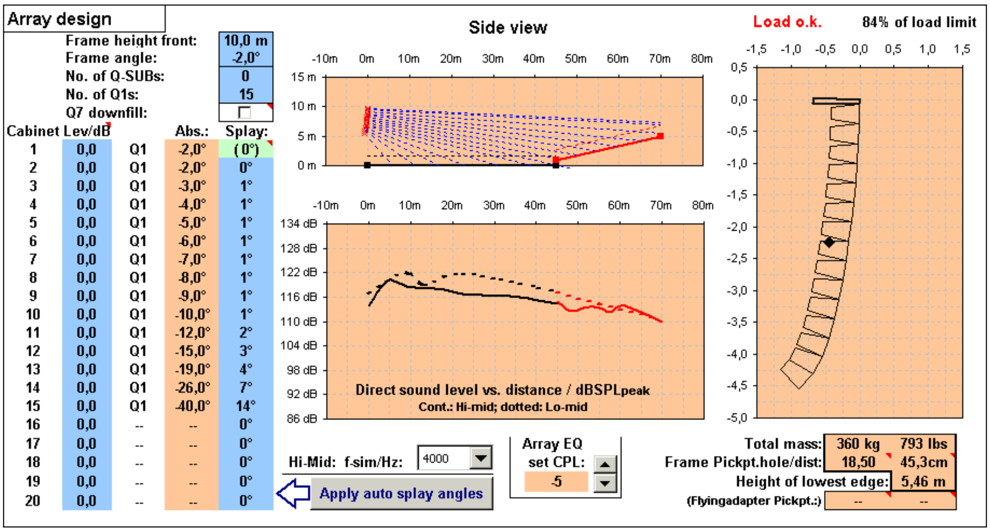
Example 4: six Q1s theatre type venue



Example 5: twelve Q1s theatre type venue



Example 6: eight Q1s arena type venue



Example 7: fifteen Q1s arena type venue

9. Q-CalcStack

Q-CalcStack works in a very similar way to Q-CalcRig.

As there is no Flying frame the aiming of the cabinets has to be done with splay angles only, starting at the lowest Q1 cabinet (there is no "Auto splay" algorithm available). The height of the system is defined by the stage height and the number of Q-SUBs.

Stage/riser height:	0,5 m
No. of Q1s:	3
No. of Q-SUBs:	3

Cabinet	Lev/dB		Absol.	Splay
6	0,0	--	--	0°
5	0,0	--	--	0°
4	0,0	--	--	0°
3	0,0	Q1	0,0°	0°
2	0,0	Q1	0,0°	6°
1	0,0	Q1	-6,0°	0°

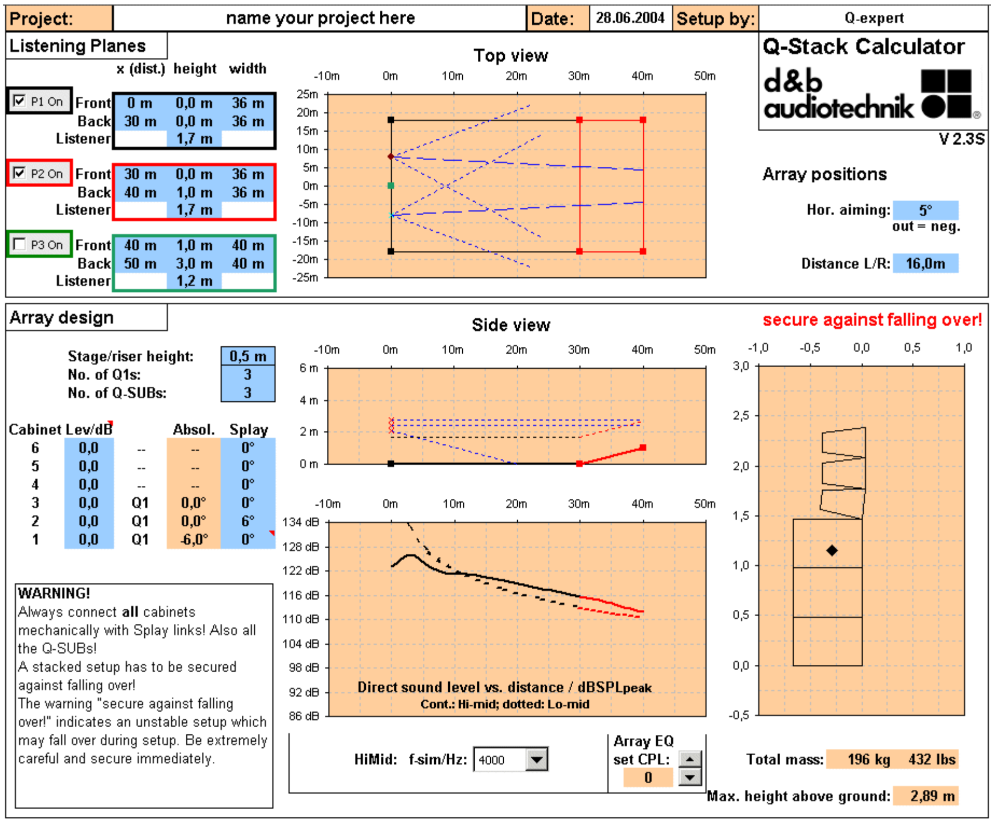
The first splay value to the top Q-SUB cabinet represents the setting according to the scale on the splay link. Due to the location of the pins in the Q-SUB cabinet the actual splay angle between these cabinets has an offset of 6°. The set up is best adjusted while watching the absolute angles of the Q1 cabinets.

With ground stacked systems the low / mid SPL curve will generally show an increase at the very front when approaching the stack. Creating a similar curve for the high / mid frequencies is not advised as to achieve this the Q1s would have to be placed at the level of the listeners ears. This would create dangerous sound pressure levels at the front, and would not reach the audience at the rear.

Ground stacked arrays must be secured to avoid either movement or the collapse of the stack. If Q-CalcStack displays the warning:

secure against falling over!

the set up and securing of the stack must be handled with particular care.



Q-CalcStack array calculator