TI 323 (Version 6.0)
C4 System
Specifications and configurations

d&b
audiotechnik ®

General Information

Technical Information TI 323

Version 6.0E, 03/2003, D5323.E.06

The information presented in this document is, to the best of our knowledge, correct. We will however not be held responsible for the consequences of any errors or omissions.

Technical specifications, weights and dimensions should always be confirmed with d&b audiotechnik AG prior to inclusion in any additional documentation.

C-Series
A modular concept

The d&b audiotechnik **C4 system** has been specifically optimized for flexible, modular array configurations and high sound pressure levels. Applications range from professional touring industry use and large scale sound system installations, down to single cabinet set ups requiring narrow dispersion over a wide frequency range with minimum dimensions. The "d&b specific" combination of a natural, intelligible sound character that is clear and transparent even at high sound pressure levels provides the engineer with an efficient, effortless tool and a neutral platform for the creative part of his work.

d&b's co-operation with MAN flying systems resulted in a flexible mechanical structure for quick and easy set up of array configurations with small footprints. All relevant parts of the system have load safety factors type approved to the German BGV C1 safety standard. Software support for planning and calculating flown set ups, regular safety checks, certification for mobile systems and training seminars for practical handling aspects and safety conscious use, all add up to complete the mechanical concept of the C4 system. Centralized computer set up, control and maintenance has been a feature of d&b systems from the very beginning. All mainframes can be networked via the d&b Remote Interface Bridge (RIB), and with the addition of the d&b ROPE software package user specific system control and monitoring is accessible.

d&b is acutely aware that managing a rental business puts tight requirements on the logistics and flexibility of a system. Technically autonomous systems can be combined and split in a wide variety of combinations. Light weight, a compact size that takes into account standard truck widths and modular packaging of the electronics all result in time, space and cost benefits when commissioning and transporting the system. In addition the full acoustical, mechanical and electrical compatibility of all d&b systems worldwide, results in high flexibility and availability when scheduling events. This is d&b's system approach: all loudspeakers, electronics, mechanics, design tools, documentation and training, support and service are designed and matched for the ease of the sound designer, the system and balance engineer, the warehouse manager and the system owner.

d&b systems are serious investments, however they excel in return on investment versus total cost of ownership. For medium to large scale sound reinforcement applications the **C3**, **C4-TOP** and **C4-SUB** loudspeakers form the basis of a modular, arrayable system, along with the **B2-SUB** infrabass. The C3 is the line array module for the C4 system. It distinguishes itself from conventional line array concepts in several respects. First of all, with its horizontal dispersion of 35°, it is meant to be part of a larger array that can be precisely designed for the specific horizontal and vertical coverage that is actually required in an application. If necessary, it allows for flawless horizontal coupling when wider coverage over longer distances is needed. Secondly, it works as a 2 or 3 cabinet column within a C4 cluster, adding long throw capability for the high end. And, last but not least, with its unique wave front adapter that couples a total of three 1.3" exit drivers, it exhibits superbly controlled curved coherent wavefronts up to 16 kHz at any vertical angle between 1° and 5°. This also allows a full line array approach without losing HF efficiency. Theoretical studies, computer aided design and extensive practical tests led to the influential, but unequalled coaxial horn-in-horn design of the C4-TOP loudspeaker. It is the constant directivity module of the C4 system and features an exceptionally constant and narrow 35° x 35° dispersion down to 700 Hz. The C4-SUB has been designed specifically as the flown subwoofer in a C4 system. Its frequency response extends down to 50 Hz, and its cabinet shape, size and flying arrangements are totally compatible with the C3 and C4-TOP. For extended low frequency reproduction, the B2-SUB infrabass system is used. The low end of the frequency range is produced much more efficiently in a ground coupled configuration, and for this reason there are no flying fittings on a B2 cabinet. Near field requirements can be met by the C7 and MAX systems. The C4 system and B2 are driven by the **P1200A** and **A1** mainframes respectively.

The following TI describes the loudspeakers and their characteristics, system amplification, connections, acoustical parameters, system design and the rigging concept, devices and tools. It also contains examples of proven system set ups of various sizes.

1. The loudspeakers and their characteristics

MAX
85 Hz -18 kHz / 133 dB SPL*
60° conical
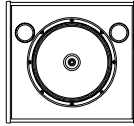
MAX is a passive full range system with a 15"/2" coaxial driver. MAX is available with flying studplates as an option and therefore can be integrated into flown set ups as a dedicated C4 downfill. The shape of the cabinet also allows horizontal arraying of multiple MAX cabinets when used as a stacked near field system. To ensure correct coherence with d&b subwoofers it is recommended to use a P1200A fitted with ampMAX (passive mode) or AMP/L modules.
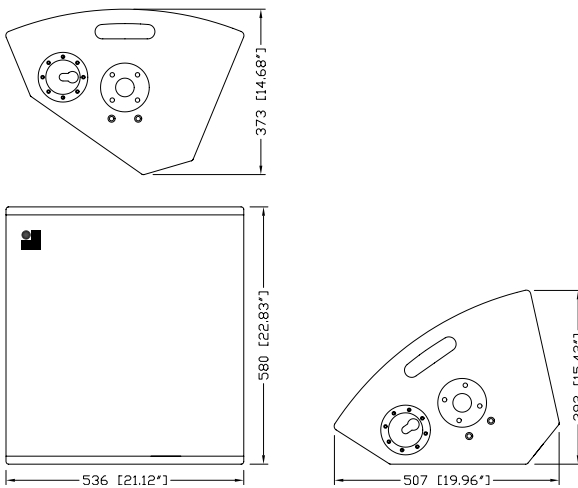
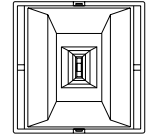**Dimensions in mm [inch]**
Weight: 26 kg/57 lb
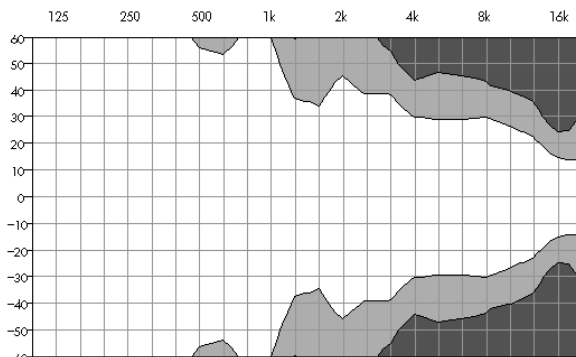
MAX dispersion characteristics**

* 1 m, free field; Broadband measurement, pink noise, crest factor 4,
 peak measurement, linear weighting
** Dispersion angle vs frequency plotted using lines of equal sound pressure
  (isobars) at −6 dB and −12 dB

C7-TOP
**68 Hz -18 kHz / 136 dB SPL***
75° horizontal x 40° vertical

The C7-TOP is equipped with a 15"/1.5" coaxially mounted hornloaded driver combination in a vented enclosure. The use of coaxial horns gives the C7-TOP a controlled, even dispersion pattern from a compact cabinet. The high output capability of the C7-TOP allows it to operate in the most demanding PA applications. With a horizontal dispersion of 75° making it ideal to complete a C4 array covering mid to near field areas and side seating tiers. In combination with the C4-SUB, the C7-TOP must be operated in CUT mode only.
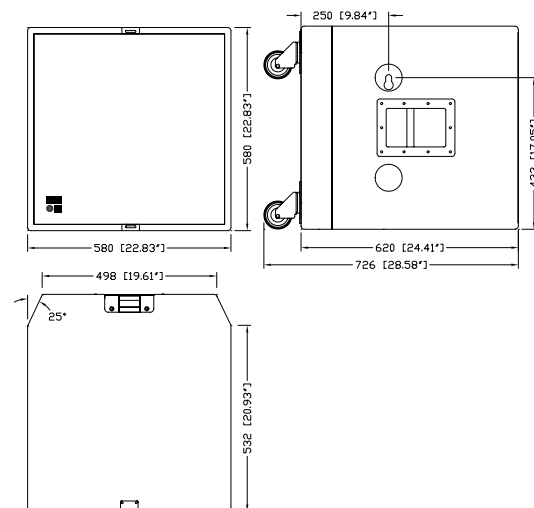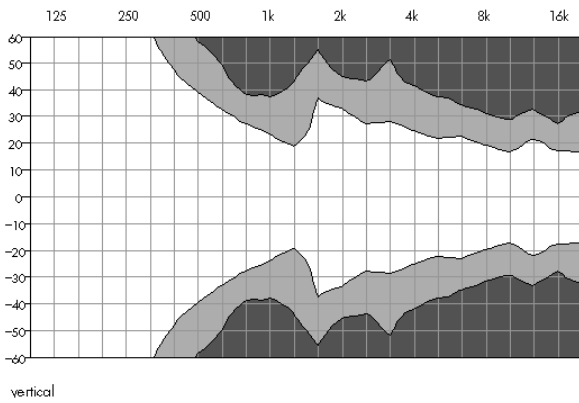
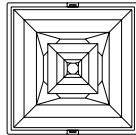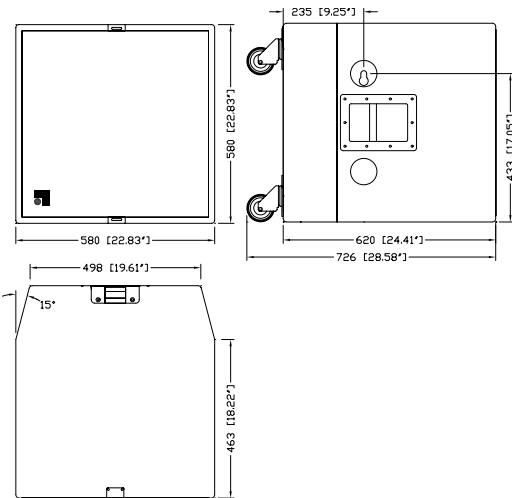**Dimensions in mm [inch]**
Weight (incl. wheels): 52 kg/117 lb
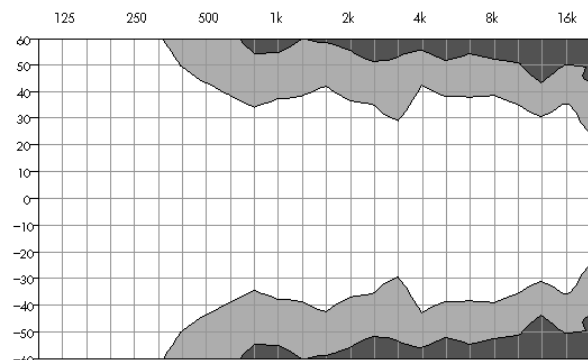
vertical
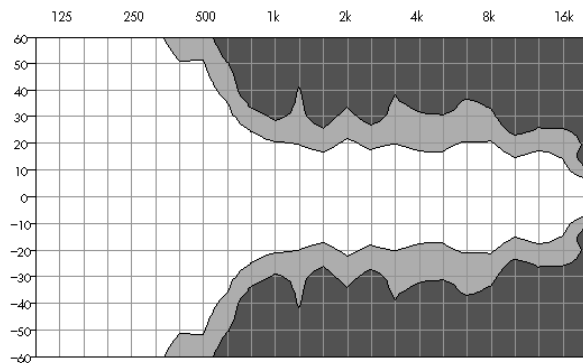
C7-TOP dispersion characteristics**

C4-TOP
150 Hz -18 kHz / 138 dB SPL*
35° horizontal x 35° vertical

The C4-TOP uses a 12"/2" driver combination in a coaxial horn-in-horn design. The shape and acoustic design (the use of CD horns) of C4-TOP cabinets enables them to be arrayed for increased coverage. The high output and long throw capabilities of the C4-TOP allows coverage to 30 metres (98 ft) and beyond. The dedicated C4-TOP controller module, incorporates a HFC circuit (High Frequency Compensation) to make up for the high frequency absorption of air over distance.
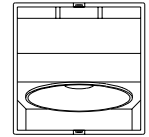

Dimensions in mm [inch]
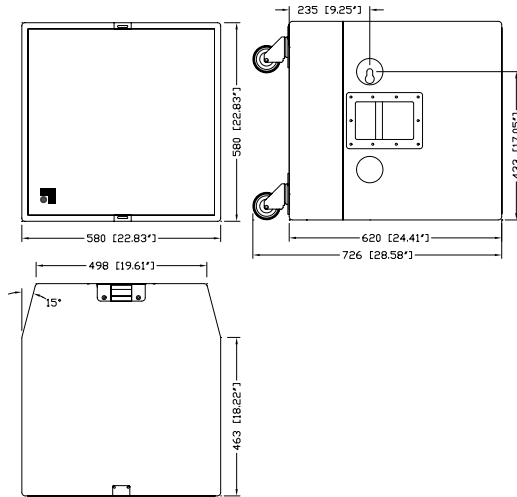**Weight (incl. wheels): 58 kg/128 lb**

C4-TOP dispersion characteristics**
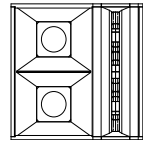
C4-SUB
50 Hz - 150Hz / 133 dB SPL*

The C4-SUB uses a 18" driver in a compact bandpass horn design. As a part of the C4 system, the C4-SUB is designed to be used with the C4-TOP.
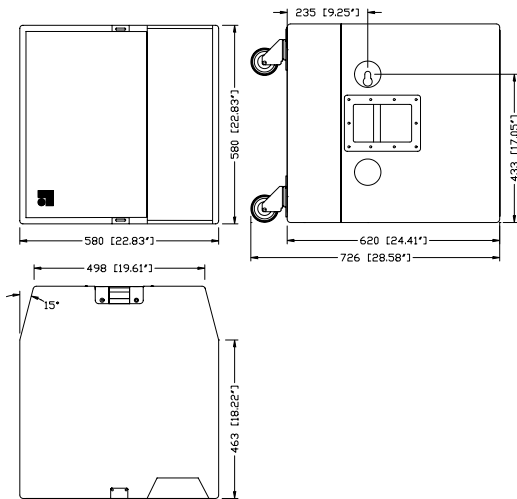

Dimensions in mm [inch]
Weight (incl. wheels): 48 kg/106 lb

C3
130 Hz - 16 kHz[1]
(Standard mode) / >143dB SPL*
80 Hz - 16 kHz[1]
(LFC mode) / > 140 dB SPL*
35° horizontal x 5° vertical

The C3 is an active, biaxial speaker system, which consists of two hornloaded 10" mid-range drivers and three 1.3" compression drivers. The horizontal dispersion is the same as the C4-TOP and therefore these cabinets can be combined in an array with a standard horizontal splay of the cabinets between 20° and 30°. Due to the narrow vertical dispersion and the shape of the wavefront of the C3, this cabinet extends the far field of the C4 array by using cylindrical wavefront technology. The purpose of the C3 is to cover the far field starting from 40 metres (131 ft) and beyond. The dedicated C3 controller module is designed to create a flat frequency response with two cabinets and a vertical splay of 5°. The dedicated C3 controller module incorporates an HFC (High Frequency Compensation) switch to compensates for the excessive losses of the HF band over distances and a LFC (Low Frequency Compensation) to shift the lower corner frequency down to 100 Hz. This switch can be used for speech reinforcement without additional subwoofers.

[1] Two cabinets
* Broadband measurement, pink noise, crest factor 4, peak measurement linear weighting
** Dispersion angle vs frequency plotted using lines of equal sound pressure (isobars) at –6 dB and –12 dB

Dimensions in mm [inch]
Weight (incl. wheels): 71 kg/156 lb
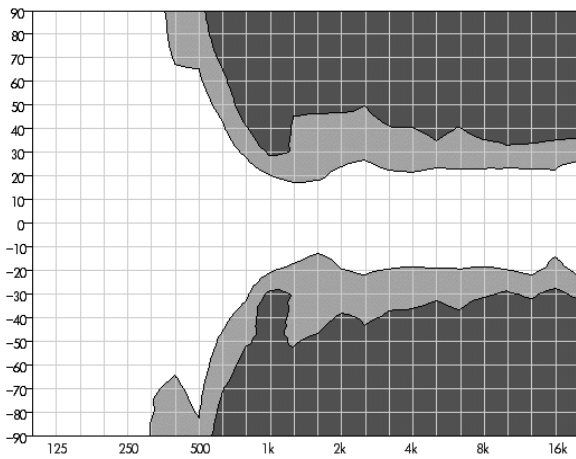
C3 horizontal dispersion characteristics**

B2-SUB
32 Hz - 68 Hz
(Infra mode) / 136 dB SPL*
37 Hz - 125 Hz
(Standard mode) / 139 dB SPL*

The B2-SUB uses two 18" drivers in a bandpass horn design. In the examples discussed in this TI the B2-SUB is used as an infrabass enhancement for C4 systems (combined with C4-SUBs) and exclusively used in Infra mode.
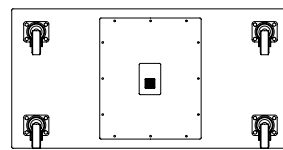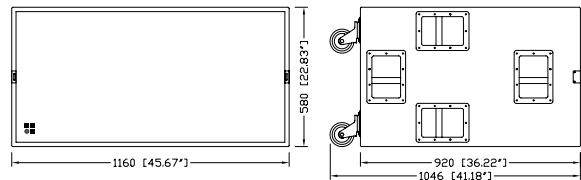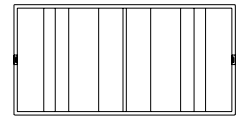
Dimensions in mm [inch]
Weight (incl. wheels): 102 kg/225 lb

* 1 m, free field; Broadband measurement, pink noise, crest factor 4, peak measurement, linear weighting
** Dispersion angle vs frequency plotted using lines of equal sound pressure (isobars) at −6 dB and −12 dB

2. System amplification

Suitable for use with all d&b C-Series systems, the **P1200A mainframe** (2 x 600 W / 4 ohms) has two front panel slots to accommodate one or two loudspeaker specific controller modules. In the case of the C4/C7 loudspeakers one channel of a P1200A mainframe can drive up to two cabinets.

Single mainframes can be fitted with both TOP and SUB modules to drive mid/high cabinets on one channel and subwoofers on the other, two C4-TOP and two C4-SUB loudspeakers can then be fed by a single four core cable from the mainframe and connected in a daisy chain.

Alternatively, single mainframes can be fitted with two identical TOP or SUB controller modules to create stereo mid/high or subwoofer systems.

The C3 loudspeaker is a 2-way active design and therefore requires both channels of a P1200A. Up to two C3 loudspeakers can be driven by a P1200A power amplifier fitted with the C3 controller module. To avoid HF loss with long cable runs each cabinet must be connected to one of the mainframe outputs using separate cables with a minimum conductor size of 4 x 2.5 mm^2 (13 AWG).

The **A1 mainframe** (1200 W/350 W/4 ohms) the dedicated mainframe for d&b's active systems. Fitted with a B2 controller module it drives the B2-SUB which is used for infrabass enhancement of C4 systems. The B2 controller also provides a filtered and buffered low impedance output, the C4 OUT, that can be used to drive C4 controllers when they are used in combination with B2-SUBs.

The modular nature of these individual systems lends itself to the creation of customized sound reinforcement designs which allow for future expansion or reconfiguration when the need arises.
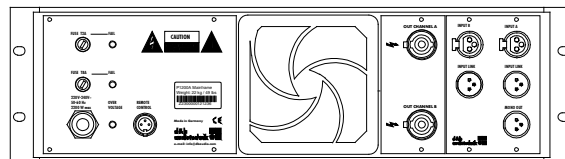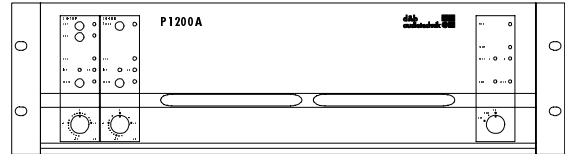
Dimensions (HxWxD): 3 RU x 19" x 13.9"
Weight: 22 kg/48.5 lb (with modules)
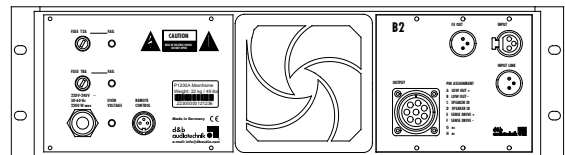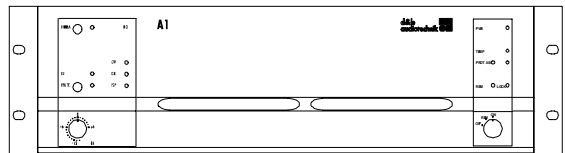
Dimensions (HxWxD): 3 RU x 19" x 13.9"
Weight: 22 kg/48.5 lb (with modules)

3. Connections

INPUT SIGNAL ▶
NOTE: INPUT B is not used !

P1200A

C3 CONTROLLER

OUT 1
OUT 2

d&b MC4 — C3
d&b MC4 — C3

OUT 2
OUT 1

LINK OUT C4

INPUT A

P1200A

C4-TOP/C4-SUB
CONTROLLER

LINK

d&b MC4 — C4-TOP
d&b MC4 — C4-TOP
d&b MC4 — C4-SUB
d&b MC4 — C4-SUB
OUT CHANNEL B — d&b MC4 — C4-SUB

INPUT SIGNAL ▶

C4 OUT

A1
B2

B2-SUB
CONTROLLER

OUTPUT — d&b MC8 — B2-SUB

LINK OUT
FULLRANGE
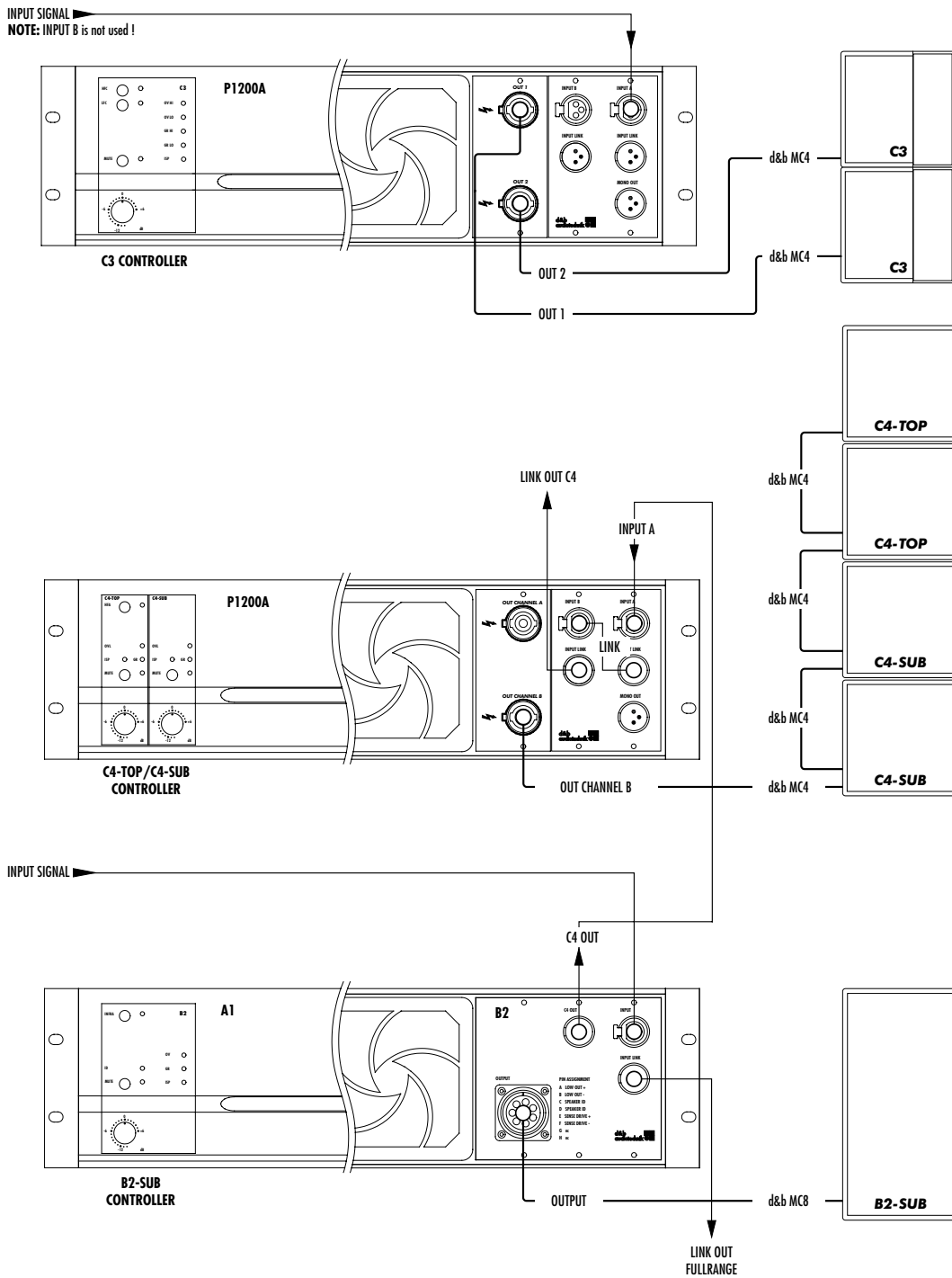
3.1. Line signal connection

Line level signal wiring needs much more care than most people believe. In total there are three major factors to consider:

− The output impedance and maximum output current capability of the driving device.
− The length of all connecting cables.
− The total capacitance between the signal conductors (between pins 2 and 3 of corresponding XLR connectors).

The number of controller input channels that can be connected in parallel is limited by their total impedance and the output capabilities of the drive unit. Standard balanced outputs of most signal processing equipment are rated for load impedances of > 600 ohms while each channel of a P1200A mainframe has an input impedance of 44 kΩ.

Where multiple units of equal impedance are connected in parallel, the aquivalent total load impedance is halved with each doubling of the number of units connected. In the case of the P1200A mainframes this would allow a theoretical maximum of approximately 64 input channels (32 dual channels of P1200A) to be connected to a standard balanced output. To maintain full available headroom, a standard 600 ohms rated output should not be loaded with less than 2 kΩ (corresponding to 22 channels or 11 dual channels of P1200A). With most output stages, anything less immediately results in a drastic reduction of available headroom.

Extra care must be taken when low impedances are driven via long multicore cables: the small capacitive load of the cable is effectively paralleled to the receiving inputs. Capacitive loads dramatically decrease drive capabilities of most output stages due to additional phase shifts caused by the low pass filter formed by the output impedance and the capacitive load. As a rule of thumb, not more than 12 channels (6 dual channels of P1200A) should be connected in parallel to one 600 ohms rated drive line via a multicore.

Where a large number of controllers have to be driven with the same signal, especially via long cables, suitable line drivers should be used and/or the system must be subdivided using multiple outputs and signal lines.

The C4 OUT circuit of each B2 controller offers a very low impedance line driving capability (actual output impedance < 20 ohms), and can deliver full headroom into virtually any load.

Tips:
Use the C4 OUT provided on an A1/B2 controller to drive P1200A mainframes for C4 systems. The C4 OUT provides a filtered and buffered signal to the C4 controllers and effectively limits the lower frequency range of the C4-SUBs to 60 Hz. The frequencies below 60 Hz are efficiently covered by the B2s, while the C4-SUBs can benefit from the extended headroom available.

Using the C4 OUT, with its low impedance line driving capability, is also a useful way to avoid drive line impedance problems in larger systems. Where failure of an A1/B2 controller occurs, including loss of mains power, the input signal is automatically switched by a relay to provide a hardwired connection to the C4 OUT. Do not use the MONO OUT of a mainframe to overcome the problem of drive line impedance. The MONO OUT provides a signal which is a −3 dB sum of channel A and channel B. If you apply the same signal to both channels their sum is +6 dB, the MONO OUT signal in this case would be +3 dB. The resulting gain structure within the system would be compromised with controllers driven in this manner running at a higher level. In large set ups where multiple B2 systems are fed from separate auxiliary or matrix sends, independent from the master send, C4 systems can be fed from one or more of the A1/B2 controllers per side leaving the majority of B2 systems under independent control.

Be careful with digital equalizers: digital equalizers always have a nominal delay (latency) of around 1 to 3 ms, even when their delay setting is on zero.
When using different drive lines for a system it is essential to make sure that every channel used has the same delay time, including taking into account the conversion delays of any digital equalisers or other processing units.
Different delay times can have disasterous effects on signal coherence; at its best this results in a loss of acoustic energy, at its worst frequency dependant lobes are created in various directions.

When using a ratio of more than one B2 to four C4-SUBs, we suggest a reduction in the input level to the B2s to maintain an even frequency response of the overall system, while increasing the low frequency headroom. If a lack of punch is observed, very often the relative B2 level is simply too high. The "punchy" part of the bass is in the frequency range handled by the C4-SUB from around 70 to 150 Hz and therefore too much B2 energy masks all direct percussive output signals.

3.2. Speaker wiring

d&b recommends the use of high quality loudspeaker cable of sufficient wire diameter. Do not be fooled by tables presenting huge numbers in Watts of power loss for a specific combination of wire diameter, load impedance and cable length. A loss of 200 Watts or 20 % of the power, from 1000 Watts sounds a lot, but keep in mind that this is approximately 1 dB in terms of level. A 2.5 mm^2 (10 AWG) cable is recommended in order to keep the losses below 0.5 dB when connecting a 4 ohm load over a distance of up to 30 metres (98.4 ft). If the load is 8 ohm, the length can be doubled. If the distance is greater, the wire diameter has to be increased.

3.3. Mains power supply requirements

Power consumption of amplifiers is dependent on many factors including load impedance, signal level and signal characteristics (speech, music). A key factor in estimating amplifier power consumption is the crest factor (CF) of the applied signal. The crest factor is a measure for the ratio of peak to RMS voltage of a signal.

The table below shows the total average output power and the corresponding power consumption of a P1200A (the figures are similar for an A1), driving 4 ohm loads (both channels) to the clipping point of both mainframe power amplifiers.

Signal	CF	P_{out}	P_{in}
Squarewave	1	1900 W	**2600 W**
Sinewave	1.4	1200 W	**1830 W**
Pinknoise/ compressed music	3.5	200 W	**500 W**
Dynamic music	5	100 W	**300 W**
Speech/highly dynamic music	8	40 W	**200 W**

In reality, even if the system is driven hard, with compressed music, limiters engaged, the average power consumption will hardly exceed 1000 Watts per mainframe. Standard power supply ratings of
16 A/230 Volts allow up to 3 P1200A/A1 mainframes to be connected. A single phase 32 A takes up to 6 mainframes etc. Standard power supply ratings of 30 A/ 100-115 V can also accommodate 3 mainframes.

The built in soft start circuitry limits each mainframes inrush peak current to 5 A/230 V (10 A/100-115 V). This prevents circuit breakers from tripping.

4. Acoustical parameters

4.1. Power and bandwidth

The C4 system (C3, C4-TOP and C4-SUB) is a flexible modular sound reinforcement system.

The TOP/SUB ratio can be adapted to the power and bandwidth required for the specific program material:
– speech only reproduction
    2 x C4-TOP/1 x C4-SUB or
    2 x C3 in LFC mode
– light music program
    1 x1 C4-TOP/2 x C4-SUB or
    2 x C3/4 x C4-SUB)
– full range music
    4 x C3/4 x C4-SUB/1 x B2 or
    4x C4-TOP/4 x C4-SUB/1 x B2

Modular hardware design and arrayability enable the scaling of a system for any coverage and SPL requirements.

4.2. Level requirements

It is difficult to give a general recommendation on the sound pressure level (SPL) needed for specific applications. The suitability of a system is linked to a number of factors such as the program material and the nature of the acoustic environment - the size, shape and surfaces of the room, loudspeaker and audience positions etc. However, simple calculation can help clarify which type and numbers of speakers are needed to achieve a desired SPL at a defined distance.

The level produced by a loudspeaker system diminishes with distance; the propagation loss in free field conditions is –6 dB with each doubling of distance (known as the Inverse Square Law see chapter 5. Sphere or Line ?). This rule is also valid for line arrays since the 3 dB loss per doubling of the distance happens only with straight line sources.

A pair of speakers used left and right, as with a stereo system, will raise the total SPL by an average of 3 dB in their overlapping coverage (incoherent coupling). Given a stereo system where an average direct 100 dB SPL is required at the mix position 20 metres (65 ft) from stage, then the level produced by each side of the system needs to be 100 dB –3 dB +26 dB = 123 dB. An additional 12 dB of headroom should be allowed for the peak levels of dynamic program. In this case a system capable of producing 135 dB SPL per side should prove adequate (coupling of multiple systems is described later).

| distance	rel. level
2 m (6.5 ft)	– 6 dB
3 m (9.8 ft)	– 10 dB
5 m (16 ft)	– 14 dB
10 m (33 ft)	– 20 dB
20 m (65 ft)	– 26 dB
30 m (98 ft)	– 30 dB
40 m (131 ft)	– 32 dB
80 m (262 ft)	– 38 dB

4.3. Coverage

The coverage is a decisive criteria for the perception of the quality of a sound reinforcement system. Naturally, the system coverage pattern needs to be sufficiently wide to take in the entire audience (Democracy for Listeners). Narrow coverage systems can be arrayed to provide wider coverage. This works well, provided the systems used have a well defined constant directivity (CD) characteristic and can be physically arrayed at the optimum relative angle.

On the other hand it is important to reduce the diffuse sound by limiting the coverage angle of the system to audience areas only. The diffuse sound energy in a room remains largely constant whereas the direct sound energy from the loudspeakers diminishes with distance. Narrow coverage systems produce less diffuse sound energy and therefore provide a higher direct to diffuse level ratio at greater distance. This maintains a higher intelligibility and is often described as a greater 'throw'.

The three following illustrations, created in an acoustic simulation program, show the differences in the coverage of a listening area using wide, medium and narrow dispersion loudspeakers. In each simulation two stereo cabinets cover a listening area 20 m (65 ft) wide by 25 m (82 ft) long. The coverage angles, which decrease from the left, are 90° x 50°, 60° x 40°, 35° x 35°. All are at equal level in the audience area right in front of the speakers.

One can easily see, that the narrow dispersion cabinets give greater throw and higher levels towards the far field, but are compromised by uneven near field coverage.
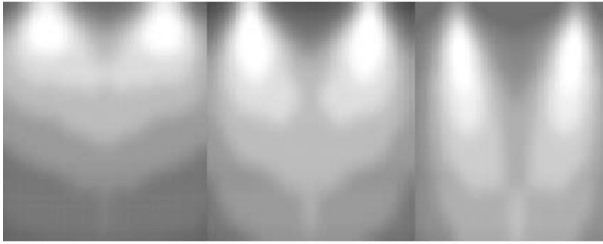
Sound pressure coverage of 90°x50°, 60°x40° and 35°x35° system

Speech intelligibility is also influenced by the variations in loudspeaker coverage. The second illustration is a plot of the Speech Transmission Index (STI) over the listening area used in the previous illustrations. There are very clear differences in speech intelligibility; white and light grey show the areas of high intelligibility. As the coverage of the loudspeakers narrows, speech intelligibility quite clearly improves in the far field.
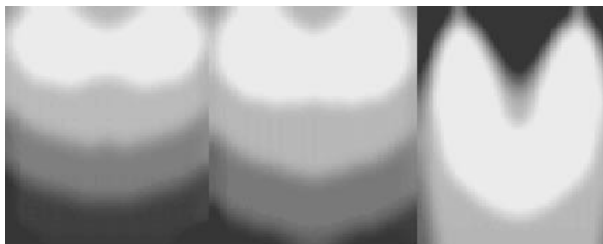
STI (Speech Transmission Index) of 90°x50°, 60°x40° and 35°x35° system

4.4.   Speaker placement considerations

4.4.1. Vertical coverage

The vertical aiming of a cabinet, the height and the angle, largely determines the sound level distribution from the source to the back of the room. To achieve the best coverage requires that the speaker height and angle are set independently. Placing the loudspeakers too low and too close to an audience will give high level near field at the expense of inadequate far field coverage. Higher speaker placement will produce more even audience coverage from the front of the stage to the back of the room.

Particularly in smaller venues, a speaker placed too high directs too much energy towards the back of the room where it can reflect off the rear wall. This will create a diffuse sound and ruin intelligibility by reducing the ratio of direct to reflected energy. It may also generate a very audible 'slap' echo. Simply tilting the speakers down and aiming them towards the audience can prevent these effects.

4.4.2. Horizontal coverage

The horizontal coverage angle of the loudspeakers should not be wider than is necessary to cover the audience area. Sound radiated in other directions adds energy into the diffuse sound field, which will decrease intelligibility.

The angled rear side panels (15°/C4/C3 and 25°/C7-TOP) indicate the horizontal arraying angle of the loudspeaker. Using these angles it is possible to verify the nominal horizontal coverage visually from behind the cabinet.

If a single system does not provide enough coverage, more cabinets can be put together in an array. This requires that systems have good constant directivity characteristics in order to keep the overlap regions as small as possible and also not leave any coverage gaps.

4.4.3. Coupling of multiple systems

If, for example, a horizontal coverage of 90° is required, it can be achieved with a single 90° system, or with three 35° degree systems with a 30° angle between each cabinet. The latter solution clearly gives more sound pressure and a much sharper level drop at the edges of the coverage area. The sharp level drop at the edges is a very valuable effect when working in highly reverberant environments, since the amount of energy wasted into the diffuse field is dramatically reduced.

Excellent constant directivity properties of a single system are essential to enable the creation of array solutions. When arraying C3 or C4-TOP systems at 30°/ C7-TOPs at 50°, an extremely smooth overlap with minimal interference is ensured (see isobar plots in chapter 1).
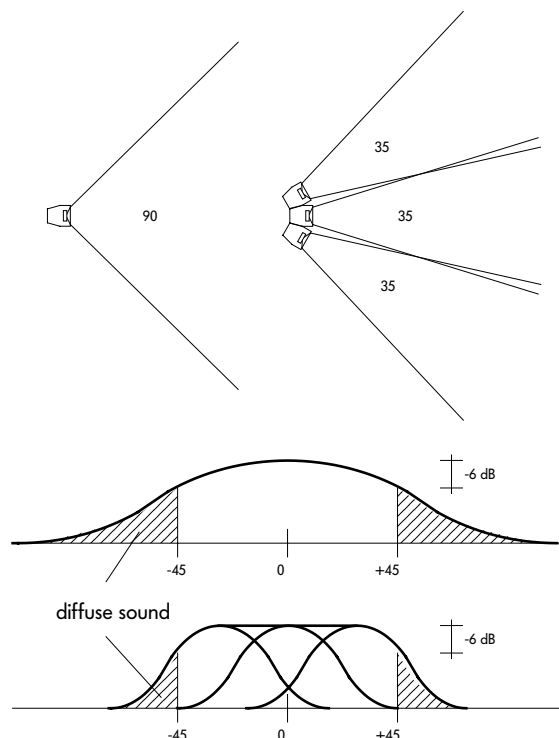
Comparison of a single 90° coverage cabinet with a 3-wide array of 35° systems

4.4.4. Comb filter effects

With more than one system per side care has to be taken to minimise the audible influence of the comb filter effect. An unavoidable problem with multiple sound sources, this effect creates a very uneven frequency response with audible peaks and cancellations due to interference across the coverage area.

What is a comb filter and how does it build up ?

If identical signals from two sources reach a point with a small offset in time, there is always a frequency for which this offset difference corresponds to the time for half of its wavelength. This signal arrives at the listening point twice, but with opposite phase. The result is a full cancellation for this frequency.

Two times this frequency is called the comb filter frequency f_{comb} for this point. The result is an in-phase arrival and, given equal levels, a +6 dB addition.

At 1.5 times f_{comb} there will be another cancellation and so on.
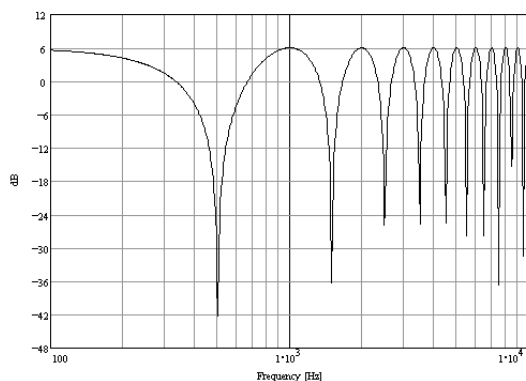
In the example above two sources of equal level and a time difference of 1ms are added.

1ms corresponds to a full cycle at f_{comb} = 1 kHz. 1/2 f_{comb} = 500 Hz, corresponding to half a cycle difference in time, at this frequency we see the first cancellation. In frequency steps of f_{comb} = 1000 Hz starting from 1/2 f_{comb} we get more cancellations.

If the levels of the sources is different, the effect stays the same, only the depth of the cancellations decreases.
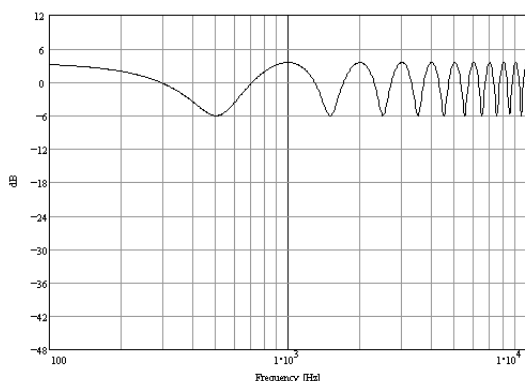
To minimise comb filter effects, the mid/high cabinets are arrayed in such a way that the coverage patterns of the loudspeakers overlap as little as possible. Arraying C3

and/or C4 cabinets using the angled rear side panels produces minimal overlap and minimal interference with maximum uniformity of frequency response over the horizontal dispersion angle.

If a system has insufficient throw for a certain direction in a room, multiple cabinets covering the same area can be stacked vertically. This minimises audible comb filter effects at audience level.

The cabinets should be placed as close together as possible, high enough and angled correctly to cover the far field only. Given that the difference in distance between the sources is rather small, filter effects are limited to very high frequencies.

Summary:

Source overlapping is acceptable in the far field because with greater distances the relative differences in path length become smaller thus minimising audible comb filter effects. The benefit is an increased SPL. Try to limit overlapping to the vertical plane which limits the areas covered by multiple speakers to the far field. Speakers covering the same area should be positioned as close together as possible in order to keep the path length distances low.

In contrast, horizontal overlapping in an array will also produce overlapping coverage in the near field. This causes highly audible comb filter effects starting in the mid frequency band and gives an increase in SPL where it is not needed.

4.4.5. Coherent signals and directivity build up

If identical signals, reproduced by different sources, arrive at a point without a time difference, these signals are called coherent.

If there is a small time difference, such that for the highest frequency of the source's operating band the time for half a cycle is still much longer than the difference in arrival time, these two sources are also summed coherently. This means that a doubling of the number of sources will result in a +6 dB level increase.

This effect can be utilized for subwoofers located close together, these will sum below a certain frequency, dependent on the total size of the subwoofer stack.

With a few subwoofers stacked together the increased level radiates spherically, so in all directions. Larger arrays will produce directivity patterns: a vertical column of subwoofers will add coherently in the horizontal plane, a horizontal line will add coherently in the vertical plane. As the listening point moves from this plane, coherency will decrease until maximum cancellation occurs.

It is only possible to direct low frequency energy by stacking subwoofers in columns. Horizontal subwoofer arrays are normally not desirable; they narrow the

horizontal dispersion while still radiating a huge amount of LF energy vertically. Vertical arrays behave more practically; they maintain a broad horizontal dispersion while narrowing the vertical pattern. A vertical array puts more energy into standard audience areas than a horizontal line of subwoofers.
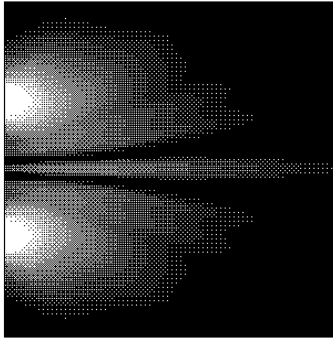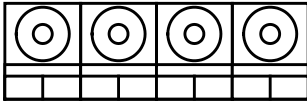
Subwoofer array for maximum horizontal directivity
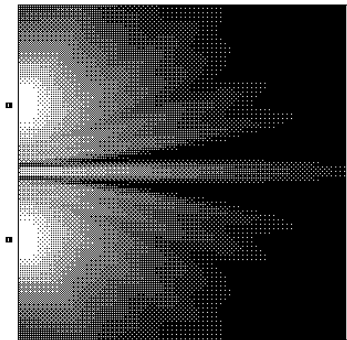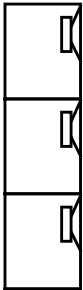
Subwoofer array for maximum vertical directivity

4.4.6. Rule of thumb

Doubling the number of subwoofers per side will give an additional 6 dB in the low end. However, when doubling mid/high systems (radiating into the same direction) the average gain in their frequency range will be around 3 dB.

For this reason there is usually a difference in ratio between TOPs and SUBs; smaller systems 1 x TOP/ 2 x SUB ratio up to a 1 to 1 ratio for bigger set ups.

All these theoretical aspects can be applied in the following array design considerations: every sound design that requires more than one cabinet, either for SPL, or for coverage reasons, or a combination of both, is a trade off between comb filter effects, the resulting SPL over the audience area and as a further result of the above, uniformity of frequency response. The Democracy for Listeners.

4.5.   Atmospheric effects

The propagation of a sound wave depends on the properties of the atmosphere, these effects are difficult to predict due to their chaotic behaviour.

4.5.1. Excessive HF loss

The effect of atmospheric loss is frequency dependant. With increasing frequency the transfer of energy decreases, this behaviour also depends on temperature and relative humidity. As a rule of thumb, the loss is greater with decreasing temperature and relative humidity.

The following diagram shows the frequency dependant attenuation at 100 metres (328.1 ft), 20° C with 10 %, 20 % and 50 % relative humidity.
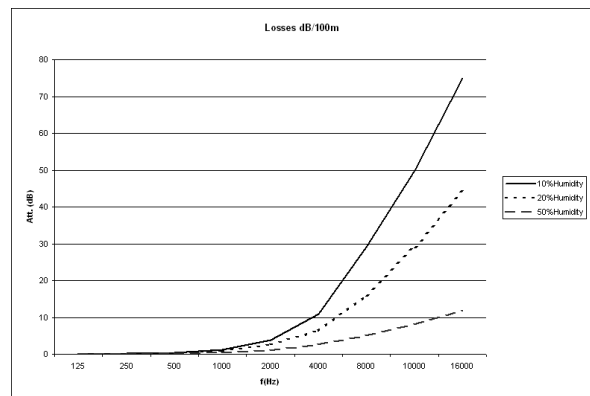
Loss over frequency at 100 metres (328.1 ft) with 10 %, 20 % and 50 % humidity

The C4-TOP and C3 controller provide a function switch HFC (High Frequency Compensation) that compensates for this transmission loss at 30 metres (98.4 ft) and 50 % humidity.
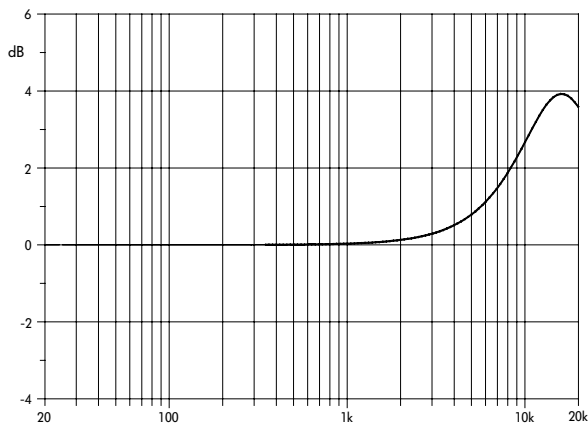
HFC function of a C4-TOP controller

Note that this filter reduces the available headroom of the loudspeaker system, and for this reason there are certain limits for electronic compensation, depending on distance and required SPL.

4.5.2. Temperature layers

The most obvious example to illustrate the effects of temperature layers in our atmosphere is an open-air show. The body temperature of the audience heats the surrounding air, while the air above them maintains the temperature of the environment. The difference in temperature can easily be 10°C or more. The table below shows the dependency between wavelength and temperature.

f (Hz)	λ (10°C)	λ (20°C)	λ (30°C)	λ (40°C)
31	10.87 m 35.66 ft	11.06 m 36.27 ft	11.26 m 36.94 ft	11.45 m 37.57 ft
63	5.35 m 17.55 ft	5.44 m 17.85 ft	5.54 m 18.18 ft	5.63 m 18.47 ft
125	2.70 m 8.86 ft	2.74 m 8.99 ft	2.79 m 9.15 ft	2.84 m 9.32 ft
250	1.35 m 4.43 ft	1.37 m 4.49 ft	1.40 m 4.59 ft	1.42 m 4.66 ft
500	64.40 cm 2.113 ft	68.60 cm 2.251 ft	69.80 cm 2.290 ft	71.00 cm 2.329 ft
1000	33.70 cm 1.106 ft	34.30 cm 1.125 ft	34.90 cm 1.145 ft	35.50 cm 1.165 ft
2000	16.85 cm 0.553 ft	17.15 cm 0.563 ft	17.45 cm 0.573 ft	17.75 cm 0.582 ft
4000	8.43 cm 0.277 ft	8.58 cm 0.282 ft	8.73 cm 0.286 ft	8.88 cm 0.291 ft
8000	4.21 cm 0.138 ft	4.29 cm 0.141 ft	4.36 cm 0.143 ft	4.44 cm 0.146 ft
16000	2.11 cm 0.069 ft	2.14 cm 0.070 ft	2.18 cm 0.072 ft	2.22 cm 0.073 ft

Due to the increasing speed of sound at higher temperatures the wavelength will increase (see chapter 5. Sphere or Line?). According to Snell's law the direction of the wave will bend depending on the thermal layers.

If the warm layer is below the cold layer the wave will bend upwards.
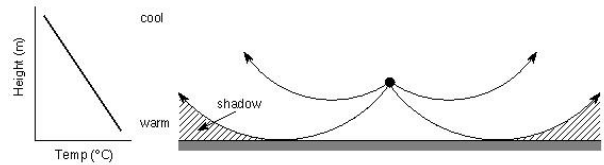
If the cold layer is below the warm layer the wave will bend downwards.
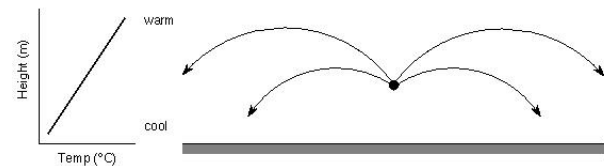
4.5.3. Wind effects

The effects described above are more or less static, however it gets more complex when looking at the effects caused by the wind. Usually the wind speed is lower near ground level than at higher altitudes, as a result if the sound wave travels against the wind the speed of sound decreases with altitude, and the sound wave will then be bent upwards.
If the sound wave travels with the wind, the speed of sound increases with altitude, and the sound wave will then be bent downwards.
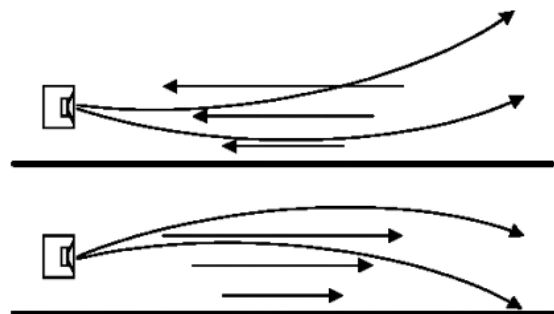

Refraction by variation of the wind speed

As mentioned before, the behaviour of the wind in the atmosphere can be erratic. Unpredictable winds creating whirlpools of rising and falling air may occur, bending sound waves in all directions.

5. Sphere or line ?

This chapter investigates the differences between spherical and line sources.

5.1. Spherical sources

An ideal spherical source is an infinitely small point. Energy radiated from such a point source is distributed spherically. Doubling the distance from the source quadruples the surface of the sphere, while the total acoustic power remains constant, therefore the acoustic power density is quartered and the sound pressure level is halved.
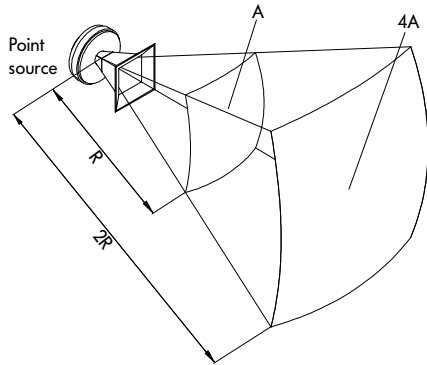
In other words, the sound pressure level drops 6 dB by doubling the distance from the source, this behaviour is known as the Inverse Square Law.
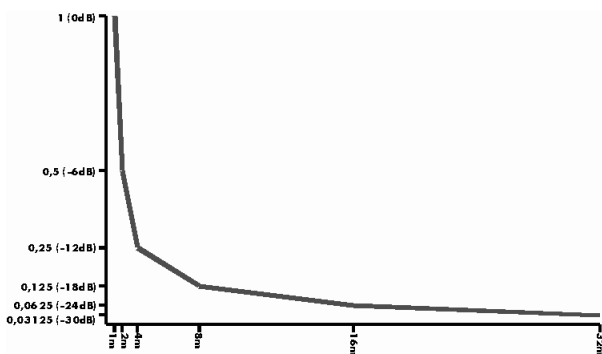
This behaviour is valid not only for ideal spheres, it is valid for all radiators where both the horizontal and vertical angle diverge.
With this knowledge it is possible to calculate the SPL for a specific loudspeaker at a given distance (D).
Usually the SPL of a loudspeaker is defined at a distance of 1 metres (3.3 ft) on axis, therefore the level drop can be calculated using the following formula:

$$SPL_{(D)} = SPL_{(1m)} - 20\log\frac{D}{1m}$$

As any loudspeaker has a maximum SPL capability, it maybe necessary to use a quantity of loudspeakers in order to increase the SPL over greater distances.

5.1.1. Combining spherical sources

Combining spherical sources to obtain various horizontal and vertical dispersion patterns requires loudspeakers that perform in a very specific manner. Placing spherical loudspeakers adjacent to each other always causes interactions between the sources. These interactions are known as comb filter effects and are described in chapter 4. To minimize the comb filter effects the loudspeakers must produce precisely controlled dispersion patterns. Splaying the cabinets to match the −6dB isobars results in minimum overlap and therefore minimizes the areas affected by comb filter effects. Usually the spread of the cabinets to the maximum possible angle can be obtained in the horizontal plane, where a very even energy distribution is essential. In the vertical plane it might be necessary to adjust the angle between the cabinets to suit the distance that has to be covered. A large vertical overlap is used between a number of boxes for the far field, while in the near field the vertical overlap decreases and a single speaker will provide sufficient coverage.
It is not possible to achieve a coherent coupling between spherical sources, especially in the HF region, as the distance between the acoustic centres is too great. A coherent addition of two loudspeakers is only possible on the axis between cabinets where both path lengths are equidistant.

### 5.1.2. Signal tuning

Due to their directional behaviour, arrayed spherical sources can be seen as single, independent components, addressing a defined part of the listener area. Coupling only happens with adjacent cabinets, below the frequency of defined directivity. Depending on the amount and arrangement of the individual cabinets a shelf filter can be applied to compensate this coupling effect.

5.2.   Line Sources

Line sources are nothing new; in the 50s it was the only economical solution to build loudspeaker systems that provided a specific directivity in a defined frequency range. Without being aware, this technology is often used today to increase the directional behaviour of loudspeaker arrays.

The ideal line source is an infinitely long, continuous radiator. Energy radiated from a line source is distributed cylindrically, doubling the distance from the source doubles the surface of the cylinder. Therefore, the acoustic power density is halved and according to power distribution the resulting SPL is the √2 or –3 dB by doubling the distance.
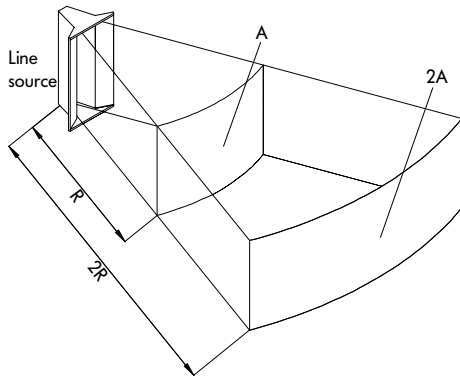
In reality continuous and infinite line sources do not exist, and therefore a number of limitations should be taken into account when predicting the behaviour of a real line array.

5.2.1. Discrete line array

A discrete line array consists of a number of drivers arrayed in a line, of which there are two variations.

Sperical sources:

The first is an array built out of spherical sources. Because of their physical size there will be a spacing between the acoustical centre of the drivers, and this distance must be smaller than the shortest transmitted wavelength.

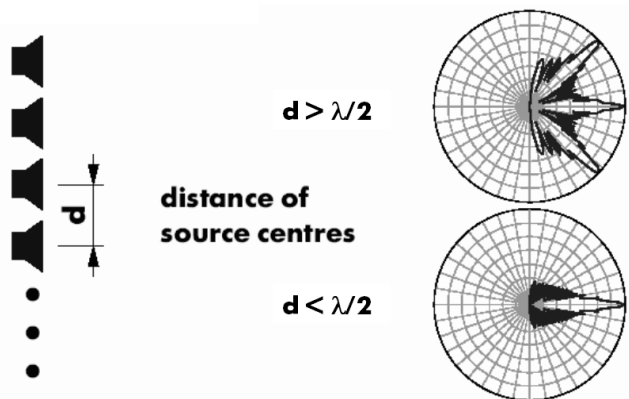The wavelength is calculated by:

$$\lambda = \frac{c}{f}$$

Where:
λ = wavelength (m)
c = speed of sound (m/s)
f = frequency (1/s)

To transmit 10 kHz (λ = 0,034 metre / 0.11 ft) the distance between the drivers must be 3 cm or less. As soon as the wavelength is shorter than the distance between them the array creates side lobes and loses its directional behaviour.

Simulation of the directional behaviour of a discrete line array. Note the lobes where the wavelength is shorter than the distance [d] between the drivers

Directional sources:

The second variation uses directional sources to create a wave front that curves slightly and this is the most common approach used in todays line arrays. The wave front radius of each single source is important to minimize the wave front offset between sources.
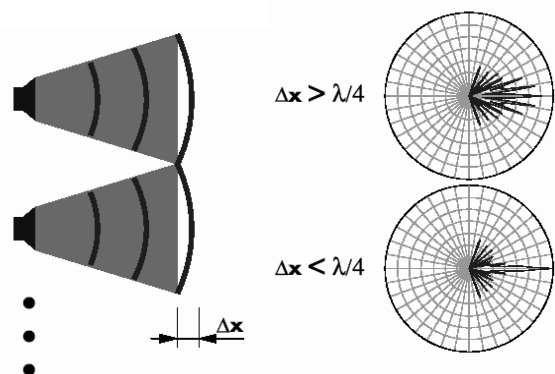
If the wave front offset [Δx] is larger than λ/4, the resulting wave front breaks up and loses its directional property.

The flatter the wave front the higher the frequency that can be transmitted.

Using magnetostatic or electrostatic ribbon drivers can improve the behaviour for very high frequencies however at the cost of efficiency, and it is for this reason that these types of drivers are very rarely found in professional sound reinforcement products.

5.2.2. Finite line arrays

The length of an array has a large impact on its properties, and due to the finite length of an array the initially cylindrical wave transforms into a spherical wave. This near field/far field transition radius is dependant on the length of the array and the frequency being produced. This radius can be calculated using the following rough formula:

$$r_{near} = \frac{l^2 \cdot f}{2 \cdot c}$$

Where:
r_{near} = near field/far field transition radius (m (ft))
l = length of the array (m (ft))
f = frequency (1/s)
c = speed of sound (m/s)

The table below shows the transition distance for a 5 metre (16.4 ft) long array at various frequencies.

| f	r in m (ft)
100 Hz	3.7 m (12 ft)
1 kHz	37 m (121.4 ft)
10 kHz	370 m (1214 ft)

The result at high frequencies is a level drop of 3 dB per doubling the distance. In other words this behaviour shows that a line array works optimally in the far field where all sources of the array arrive with minimal path length differences, and where the maximum coherent addition of sound energy occurs. Close to the array the path length differences are greater, leading to an increased incoherent addition of the sound energy radiated by the array. Comparing the line source with a spherical source radiating the same energy shows that the 3 dB level drop comes from a lack of energy close to the array. At very low frequencies a line array behaves in the same way as a normal spherical source.
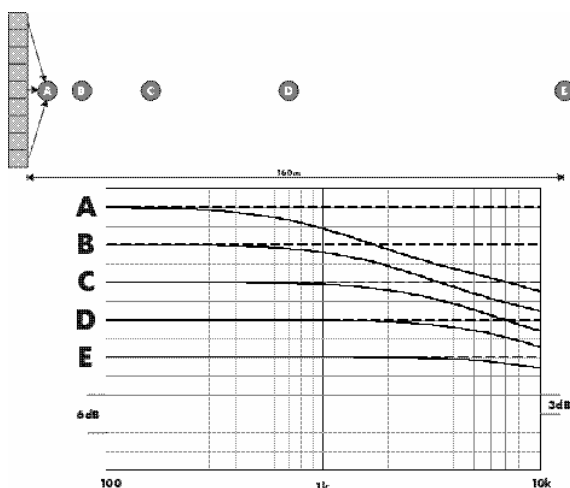
5.2.3. Curved line source

The discussion so far has only covered situations where arrays are set up in one straight line with no vertical angle set between the loudspeaker cabinets. In a typical real life situation a straight line set up will not produce sufficient coverage in the vertical plane and this requires improvement. The easiest way to achieve this is to arrange the boxes in an arc, all with the same vertical splay.

The first thing to recognize is the usual 6 dB level drop per doubling of distance. As described in the spherical sources section, the wave front now diverges horizontally and vertically, exhibiting the behaviour of a spherical source. The energy for the far field can now be adjusted by changing the overall vertical angle, halving the angle between cabinets increases the energy in the far field (and only there) by 3 dB.
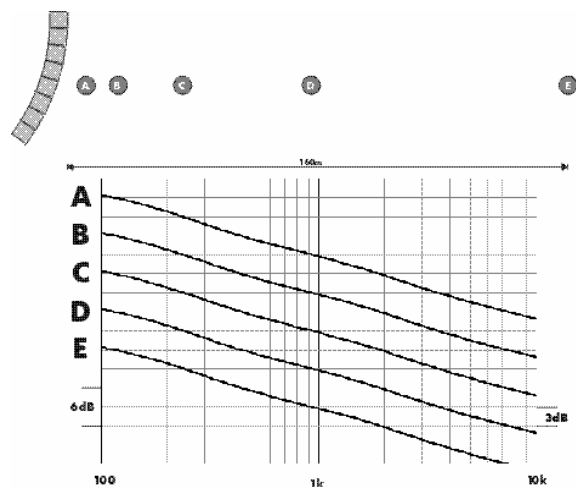
5.2.4. J-shaped line source

A J-shaped array allows adjustment to the amount of energy according to the distance that has to be covered. This means no more than the number of cabinets targeting the listener area is proportional to the distance.
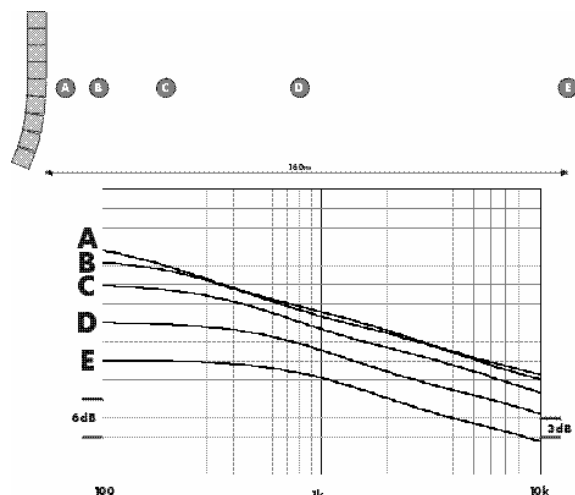
5.2.5. Signal tuning

Due to their frequency dependant coupling, curved or J-shaped line arrays require a set up related filter. The reason for this can be explained by considering the wavelength. Coherent coupling occurs when the transmitted wavelength is larger than the radiating source. It is easy to see that everywhere in the audience area the entire array combines to provide the lower frequencies, whilst at higher frequencies only a single source provides energy at any point in the listener area. The usual way to compensate for this effect is by introducing a low shelf filter, where the corner frequency and attenuation depend on the size and the total vertical dispersion angle of the array.

6. System design

6.1. Basic planing

The first consideration is the combination of horizontal and vertical dispersion angles needed to cover the audience area from specific positions. These positions should be chosen so that the system can give an acoustic orientation towards the stage for as many listeners as possible, while avoiding directing energy at close boundaries or recessed areas.

6.1.1. Step 1:

First, the total horizontal coverage angle has to be defined. Above a certain venue size it is recommended to check the far field and the mid to near field coverage requirements independently.

From this rough overview the number and the aiming of 30° sectors can be determined. The coverage angle per column for C4-TOPs and C3s should be in the range between 20° and 30°, however choosing 30° sectors results in a seamless, interference free horizontal overlap between columns (50° sectors for C7-TOP columns).

In the following example of a typical arena, far field horizontal coverage is needed for sectors 2 and 3. Mid field coverage is needed for all five sectors. Near field coverage has to be provided for sectors 1, 2 and 3.
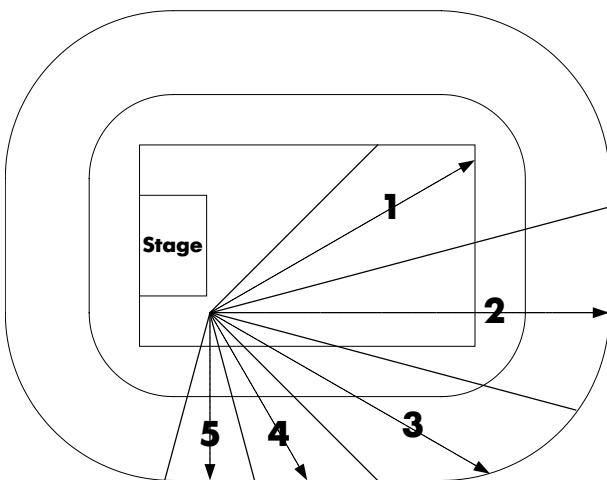

Typical arena situation, showing the necessary horizontal coverage.

Far field coverage in sector 1 should be avoided, since the target area will also be covered by the long throw component of the other main PA cluster. Due to the large difference in the path length to this area from each cluster a high level far field coverage for sector 1 would cause a second arrival, or echo and therefore decrease intelligibility dramatically.

Depending on the source program and the chosen loudspeaker type, either a 5-wide or a 6-wide set up with an additional column of SUBs to increase LF throw would be suitable.

6.1.2. Step 2:

The audience areas vertical coverage profile and throw distances have to be calculated, if necessary independently for every column specified in step 1. To achieve a uniform coverage and direct to diffuse sound ratio the SPL variation should not exceed ± 3 dB over the listener area. If, for instance, the distance to the farthest listener is 60 metres (196.9 ft) and the distance to the closest listener is about 8 metres (26.2 ft), depending on the height of the cluster, the resulting level difference is 17 dB.
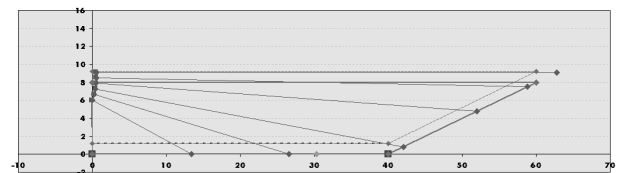
Example of a vertical profile with the main axis of the TOP loudspeakers.

Depending on the type of event, the average SPL can be defined. From this, the type, number and vertical angle of the cabinets can be determined. Using the Inverse Square Law and the level increase due to coupling, the SPL for various areas and the relative levels within the columns can be estimated. The result is a defined array of either C3 and/or C4-TOP cabinets for the vertical coverage per sector. In the example shown, sectors 2 and 3 use five C3 for far/mid field coverage with 0°, 1°, 3.5°, 6°, 11° and C4-TOP with 21° vertical down tilt. The column for sector 1 should not cover the far field, so the uppermost TOP cabinet is deployed with a −10° vertical down tilt to cover the back of the ground floor.

Referring to set up examples 8 or 9, described later in chapter 9, a modification of the column for sector 1 could be SUB-SUB-C3-C3-SUB-C4 (from top to bottom), the other columns stay as shown.

6.1.3. Sidefills, backfills, downfills and frontfills

Additional systems are needed to cover critical areas such as directly in front of a stage, or side seating tiers. For these areas it is essential to maintain total system integrity and sound character. C7-TOP or MAX fullfill this requirement as shown in the examples later in chapter 9.

Sidefill and backfill systems cover the areas beneath or behind the stage. In most cases these are located near to the stage, are rather steep tiers or galleries and need shorter throw and wider coverage angles than the main system.

Frontfill systems cover the area directly in front of the stage, the benefit is a better acoustic orientation and intelligibility in the front rows.

If the set design does not allow frontfill systems, downfills can be used to cover the area directly below the main arrays and the front of stage. MAX can be used as a complementary downfill to C3/C4/C7 systems in this situation.

6.1.4. Delay systems

There are two applications for delay systems:

Firstly, to increase the direct to reverberant ratio in areas under balconies, or behind pillars. These are usually smaller speakers that restore the high frequency range within a mostly low and mid reverberant field.

The other application is to support the main system over large distances. For indoor situations their purpose is to enable the main system to run at a lower level or to maintain sufficient direct to reverberant ratio in acoustically difficult situations, for example when there are low or reflective ceilings. In larger outdoor situations it is quite common to use delayed systems that are similar to the main systems and can deliver full energy to specific areas.

For indoor and outdoor purposes there are a few basic recommendations:

Keep the horizontal coverage angle of the single delay system narrow, 60° should be considered as a maximum. Using wide angles creates time offsets within the coverage area that are too large and intelligibility will suffer dramatically.

Delay systems should offer directivity control to as low a frequency as possible.

The omnidirectional lower frequency range will spill in all directions and be audible beneath and behind the delay system. It can also be advantageous to reduce the level of a delayed full range system below the frequency of its directivity control (LF roll off). Even when using a delay system, almost the entire bass energy has to be provided by the main system. Use your ears.

Delayed systems should be placed as close as possible to their target area, so their level and coverage can be kept under control.
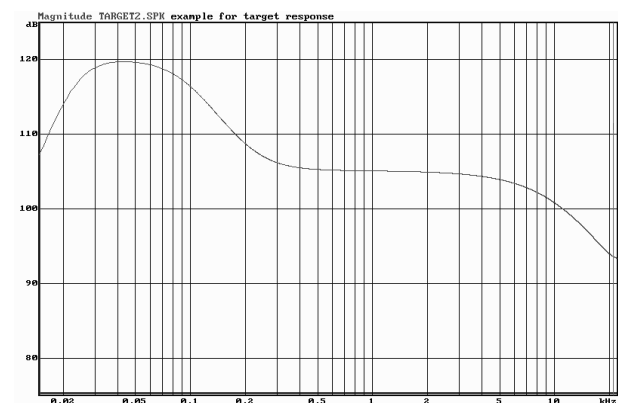
6.1.5. System tuning

Depending on the kind of system, signal processing is required to achieve a proper sound quality.

Important:

Any kind of signal processing just affects the loudspeaker. The rooms properties can not be changed!

Do not try to create a flat frequency response. Due to room acoustics a useful response would look similar the graph below.
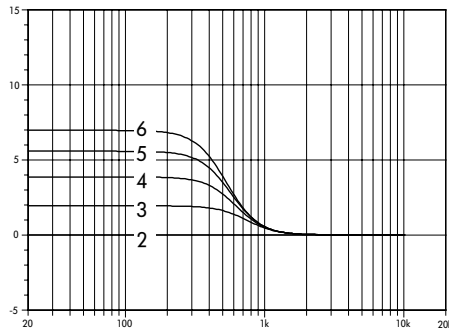

Target frequency response

6.2. Arraying C3 and C4 cabinets

6.2.1. Vertical array of C3 cabinets

A vertical array of C3 cabinets produces a precisely shaped wave front following the mechanical arrangement of the cabinets. The cutoff at the upper and lower limits of the vertical dispersion of a C3 column is very sharp, and therefore precise aiming is absolutely essential to address the desired audience area. The vertical coverage angle of a single cabinet is 5° and this defines the maximum splay angle 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 of the single cabinets. Therefore, directivity and the level of lower frequencies increases with every cabinet added to the column. Two cabinets arrayed vertically with a 5° splay angle produce a flat frequency response. Longer columns will therefore boost low and low/mid frequencies according to the graph below.
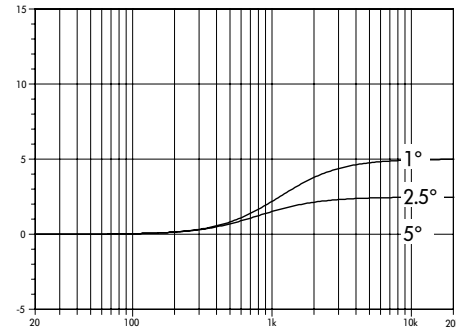

Typical change in frequency response with increasing column length (2, 3, 4, 5 and 6 deep)

This behaviour can be compensated by using a standard 2nd order (12 dB) low shelf filter. The corner frequency and gain setting depend on the number of C3 cabinets in the longest column and on the overall array size. Typical corner frequencies are listed in the table below; the gain listed applies to a single column.

Longest C3 column in array	Low shelf fc	Gain dB
3	800 Hz	–3
4	600 Hz	–4
5	450 Hz	–5
6	350 Hz	–6
7	250 Hz	–7
8	200 Hz	–8

Table of low shelf parameters for a single column

This equalization has to be used for the C3s only. C4-TOP cabinets in the array should be driven from a separate input signal feed. Decreasing the splay angle to 2.5° or even 1° will also create an overlap of the coverage patterns above 5 kHz resulting in increased high frequency output to the main axis. This effect can be used to scale the energy according to the distance and to compensate for air absorption effects when covering remote audience areas.

Typical change in frequency response when decreasing the splay angle between two cabinets from 5° to 2.5° and 1°.

This mechanical HFC equalization as opposed to the HFC circuit of the controller does not affect the headroom of the system. To achieve a smooth level distribution the vertical splay of a column is the first thing to consider when designing a set up for a specific venue. Usually the distances to the audience that an array has to cover increase from the bottom to the top of a column, consequently more power is required at the top. This can be achieved by using different vertical splay angles between cabinets in a column, with smaller angles achieving more power within a given vertical segment. For a smooth level distribution over distance it is desirable to gradually change the angle increments, e.g. 1°, –2.5°, –5° for a 4 deep column.

6.2.2. Vertical array of C3 and C4 cabinets

As their horizontal dispersion behaviour is identical, C4-TOP and C3 cabinets can be easily combined in one array. The larger vertical dispersion of a C4-TOP can be used efficiently to cover the near field in front of a C3 column. A vertical splay of 5° or 10° to the lowest C3 is useful, depending on the total height of the system.

6.2.3. Horizontal array of C3 and C4 cabinets

The horizontal angle between adjacent C3 and/or C4 cabinets in an array can be set to between 20° and 30°. The most even and widest energy distribution is achieved with 30°. Smaller angles between the cabinets will give a smaller horizontal coverage area but will produce higher sound pressure on the centre axis of the array.

The configuration of any array should be thoroughly adapted to the actual venue 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.

6.2.4. Operation with C4-SUB and B2-SUB

To extend the C3 frequency response C4-SUBs should be used. Forming columns of SUB cabinets improves efficiency and vertical directivity at low frequencies. For a balanced sound at high levels a ratio of at least one C4-SUB per C3 or C4-TOP cabinet is required. For a further extension of bandwidth and headroom ground stacked B2 subwoofers are used (INFRA mode).

6.2.5. Time alignment and signal distribution

When combining C3s and C4-TOPs the correct time alignment of both systems is of great importance. To achieve this C3 and C4-TOPs have to be driven with separate signals. With a delay of 0.3 ms in the C4 signal path both systems are perfectly coherent over the whole audio band. To avoid the influence of different latencies (inherent delays) of the signal chains, make sure that the C3s and C4s in one array are driven with the same signal processing devices using different outputs.
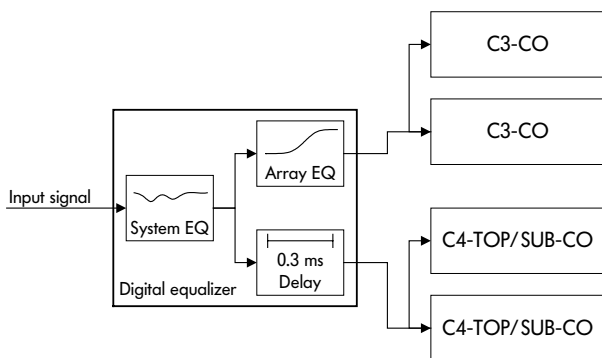

C3 wiring with C4-TOP and C4-SUB

Normally C4-SUBs will be driven from the same signal processor output as the C4-TOPs, or if B2-SUBs are used, from the C4-OUT of the B2 controller. Should the B2-SUBs be driven separately (e.g. when driven from an auxiliary output of the console or for time alignment reasons), the low cut provided by the C4-OUT of the B2 controller can also be created for the C4 using a standard parametric bandpass filter in a signal processor. The parameters are f = 44 Hz, Q = 3, Gain = −6 dB.
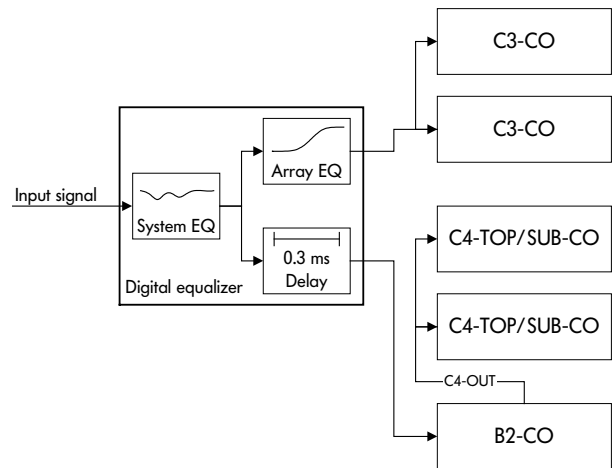
C3 wiring with C4-TOP, C4-SUB and B2-SUB

For a set up with C3s and C4-SUBs in a cluster without C4-TOPs no delay is required. Due to the low shelf filter applied to the C3 a separate signal line feeding the C4-SUBs is needed. Be aware to feed the C4-SUBs from the same digital device to maintain a common latency.
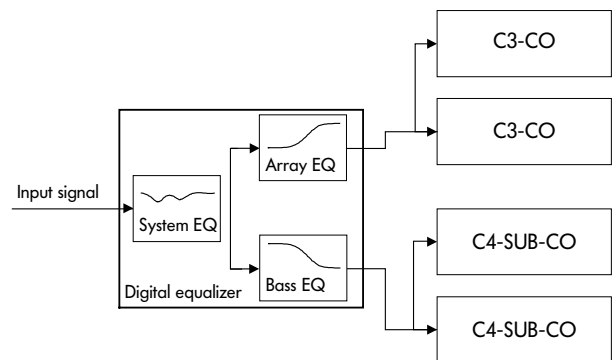
C3 wiring with C4-SUB

6.2.6. Integration into the C4 flying system

The vertical splays between the cabinets of a C4 array are set by load chains of different lengths. d&b offer chains for 1°, 2.5° and 5° angles plus a shortening chain enabling variable angles. For a coherent coupling of adjacent cabinets the precise alignment of the rear panels of the cabinets is essential. Therefore it is necessary to use the d&b Z5110.100 Hinge between the cabinets throughout the whole column. C3 arrays have a very high vertical directivity, therefore the use of a precise digital angle finder to verify the desired aiming is strongly recommended. Deviations of less than 1° can have an immense impact on the coverage in the far field. A laser distance finder is recommended to set the correct array height.

7. Rigging concept and devices

The d&b flying system provides flexibility for scaling a complete C3/C4/C7 sound reinforcement system. The flying system is designed to aim and position the loudspeaker cabinets in a way that ensures an optimized acoustic result.

All d&b flying hardware is Type Approved to the German safety regulation BGV C1.

7.1. The components

7.1.1. MAN Flying stud and CF4 Stud plate

C3, C4-TOP, C4-SUB, C7-TOP and (optionally) MAX cabinets are fitted with MAN CF4 stud plates which are designed to take the MAN Flying stud. The MAN Flying stud (also called the D-Ring) is the central component of the flying system. It is an easy to fit, self-locking device which connects the cabinet to the load bearing chains.
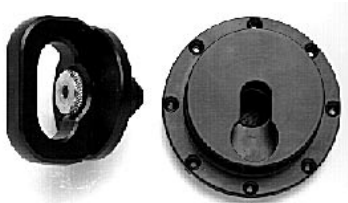
MAN Flying stud & CF4 Stud plate

7.1.2. Load bearing chains

According to BGV C1, the maximum allowed load is 560 kg (1234 lb) which is approximately the weight of 8 x C4 and 1 x MAX or 8 x C3 cabinets, including fittings.

The chains are available in different lengths:

– 11-link chains are used to suspend a loudspeaker column from a sub bar.
– 23-link chains are used to fly cabinets with a vertical angle between them of approximately 5°. 23-link chains are also recommended for use as top chains (sub bar to the top cabinet) for 6-8 deep columns.
– 1° chains are used to connect cabinets either to gain space between the columns or to couple C3s for the far field.
– 2.5° chains are the next angle increment to C3 cabinets.
– 47-link shortening chains (left and right versions), are used to adjust the vertical angle between cabinets in 5° increments.

7.1.3. Ratchet strap

The ratchet strap is used to set the vertical angle of the loudspeaker column. It is not a load bearing component in the whole assembly. d&b offers 2 ton, 12 m (39 ft) straps for columns up to 8 cabinets deep.

Chains and rached strap

7.1.4. Hinge set

The hinge fits to the rear of the cabinets in a column to maintain the alignment. It has a recessed slot to accommodate a ratchet strap that speeds up rigging. The hinge set can be retrofitted to all existing C3, C4 (402)-TOP, C4 (402)-SUB and C7 (702)-TOP cabinets. It also can be used in ground stack situation to stop cabinets from moving.

Hinge in a lashed column

## 7.2. d&b flying hardware / cradles

7.2.1. d&b Installer

The Installer is a modular flying system mainly for permanent installation or touring use where the setting does not change from day to day. The huge variety of different parts enables the user to create any configuration, starting from a single column up to clusters providing 360° of horizontal coverage. Every column can consist of up to 8 cabinets and a MAX downfill. d&b provides configurations from 1 to 4-wide which include all the parts to configure the flying system for the chosen set up.

Installer 2-wide

7.2.2. d&b Transformer

The d&b transformer is a touring device where daily set up changes are required. All settings can be directly altered and Transformer 2-wide and 3-wide Main bars can be easily combined to form larger arrays using spreader bars. The spreader bar holds the Main bars at the required distance and angle. For large set ups (5 or more columns) an additional Telescopic spreader bar can be used to stabilize the whole rig and maintain the relative positions of the motor points.
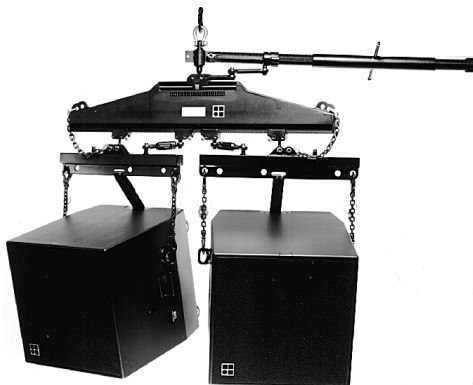

Transformer 2-wide with spreader

7.3. Vertical speaker columns

While the horizontal angles are adjusted on the flying system itself, vertical angles are set by choosing the appropriate chain and finally adjusting the vertical angle of the whole column with the ratchet strap.

Assuming that the cabinet backs are tight together, the vertical angle (α) between the cabinets depends only on the deployed length (L) of the load chains between the cabinets.
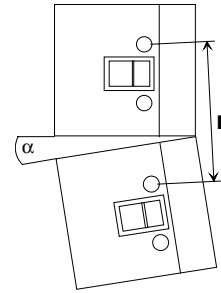

The table below shows the different angles obtained by using different chains.

Chain	Length (L)	Angle (α)
E6520	11/fixed	-
E6523	22-links/fixed	1°
E6528	fixed	2.5°
E6521	23-links/fixed	5°
E6525/26	17-links	1° - 2°
	18-links	5°
	19-links	10°
	20-links	15°
	21-links	20°
	22-links	25°
	23-links	30°

7.3.1. Suspending and adjusting the column

The vertical kelp of the whole column depends on the tension applied to the strap. Note that the centre of gravity of the whole column always remains located below the pick up point. This ensures that all the forces remain vertical regardless of the cabinet aiming.

Attachment point

Centre of gravity of individual loudspeakers (see above).

Centre of gravity of column
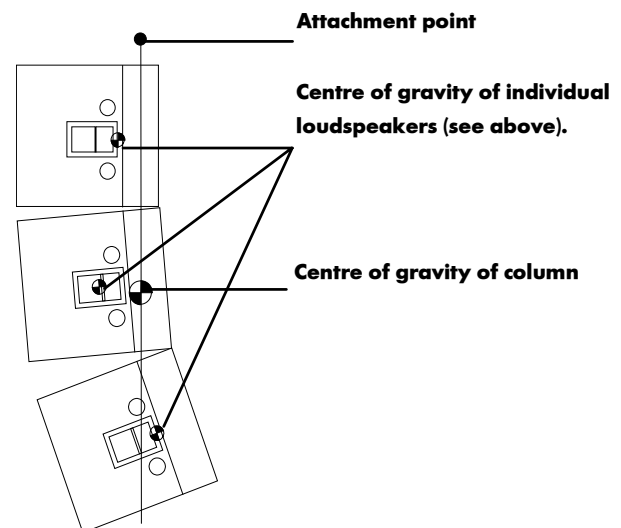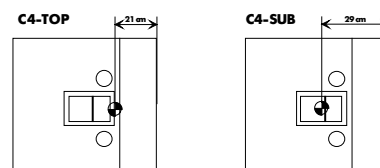
Column/centre of gravity

8. Planning tools

To accelerate the planning of an array the advanced functionality of the **TransCalc** and **InstallCalc** spreadsheets can be used. These spreadsheets are available for 2 to 6-wide Transformer set ups and for 2 and 3-wide Installer set ups.

8.1. Hardware settings

Depending on the array configuration, TransCalc and InstallCalc calculate the mechanical settings of the cradle. Inputting and retrieving data from the spreadsheets follow the same rules with slight differences according to the cradle. Aiming of the boxes are determined by the horizontal and vertical angle of the column, the applied chains and the position of the loudspeaker in the column.

The spreadsheets calculate for the entered array the mechanical settings of the chosen Transformer or Installer bar. It also determines the load for each hanging point.

8.2. Rigging plot

To achieve a precise positioning of the array TransCalc and InstallCalc provide a rigging plot to enable the rigger to exactly set the hanging points. Precise positioning of the hanging points especially for 6-wide set ups or horizontally rotated arrays is essential to obtain the desired horizontal aiming and splay between the columns. It may also be used to double check the chosen horizontal subbar setting of the individual column.
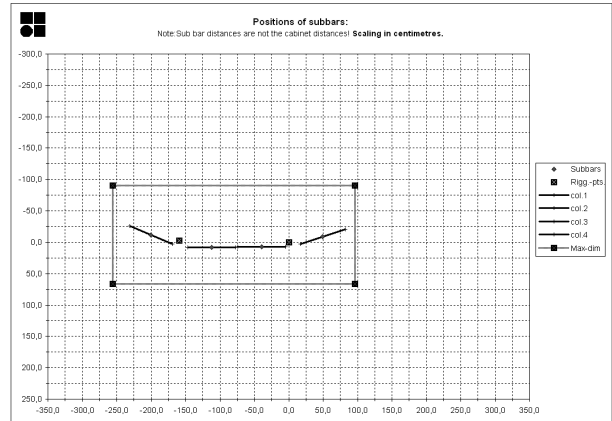
8.3. Export functions

For further planning or presentation it is possible to export the array in a 3D DXF format. This can be integrated in usual CAD programs. Another sophisticated feature is the possibility to export the loudspeaker positions and type to an acoustic simulation program such as Ease or Ulysses. This feature enables the designer or engineer to immediately calculate the acoustic properties of an array and to approximate the acoustic result in a given venue.

8.4. Parts list

Once the array is defined, TransCalc and InstallCalc provide a parts list with all necessary mechanical parts including the loudspeakers type and quantity.

| Part-List for specified 4-wide setup:		
Item	d&b Part No.	min. req. No.
Cabinets:		
C3-TOP	Z 2230	8
C4-TOP	Z 2254	5
C4-SUB	Z 2255	15
C7-TOP	Z 2257	0
MAX	Z 1100	0
RIGGING-Parts:		
CRADLE 2-WIDE	Z 5073	2
CRADLE 3-WIDE	Z 5077	0
SPREADER BAR	Z 5072	1
TELESCOPIC SPREADER (optional)		0
CHAIN 11links	E 6520	0
CHAIN "22"links / 0,975°	E 6523	8
CHAIN "22,5"links / 2.5°		24
CHAIN 23links / 5,35°	E 6521	16
CHAIN w. Clutch L	E 6526	4
CHAIN w. Clutch R	E 6525	4
STUDS	Z 5040	56
RATCHET STRAPS Std. 8m:	Z 6510.001	0
RATCHET STRAPS 12m:	Z 6510.002	4
STRAPS small for nearfil:	Z 6514.000	0
...and don´t forget to pack some spares...		

8.5. Loudspeaker aiming

As an enhanced planning aid TransCalc and InstallCalc are able to calculate the aiming of the individual TOP cabinets towards the listener planes. This is very important when using C3s in the array, due to their precisely shaped wave front.

Three sections can be defined, the floor area, side and rear tiers. Whether the audience is sitting or standing can also be defined. According to chapter 6. System design, the density of the main axis of the loudspeaker is proportional to the distance from the array to the audience area. To avoid disruptive reflections from the rear or side walls, ensure that the main axis of the long throw component only just hits the listening plane at the farthest point.

Listening Planes:

Audience is sitting   Ear height 1,2m

| Floor:		Back Stand:		Side Stand:	
width@front	60,0m	width@front	60,0m	depth:	0,0m
width@back	60,0m	width@back:	60,0m		
length:	70,0m	length:	24,0m	length@bac	0,0m
height @fro	0,0m	height @fror	0,0m	height @fro	0,0m
height@ bac	0,0m	height@ bac	8,0m	height@ bac	0,0m

SideView

TopView
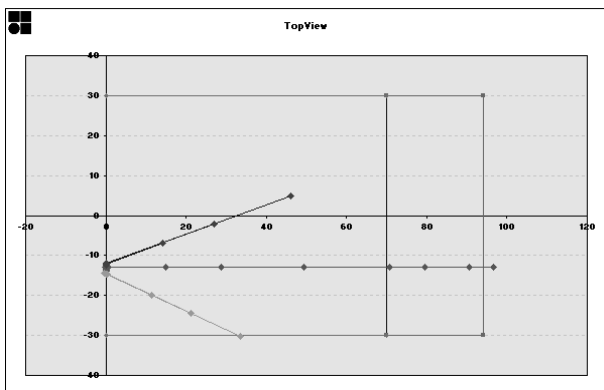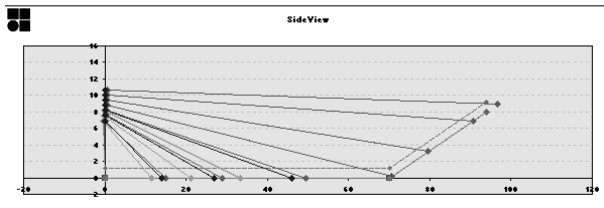
9. Examples

Positioning and placement of the cabinets next to each other and relative to the audience needs careful attention in order to achieve the best performance of a loudspeaker system. Some major issues have been explained above, the following section illustrates examples of standard applications.

All drawings show PA left, viewed from front of house.

These examples are guidelines for a final system design. This is a compilation of proven set ups that can be adapted to particular situations, in most cases by simply modifying a few angle settings, or exchanging cabinets.

9.1. Example 1:
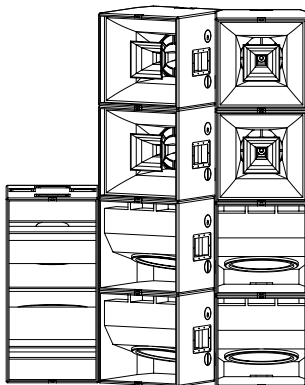
The basic C4/B2 configuration:
4 x C4-TOP, 4 x C4-SUB, 1 x B2-SUB, 2 x P1200A with mixed C4-TOP/C4-SUB controller modules,
1 x A1 with a B2 controller module. This is suitable for medium sized venues and provides a nominal 70° horizontal dispersion.

9.2. Example 2:

6 x C4-TOP, 6 x C4-SUB, 2 x B2-SUB, 3 x P1200A with C4-TOP/C4-SUB controller modules and
2 x A1 with a B2 controller module.
This shows the system scaled up from example one to give 90° horizontal dispersion and high power low end.
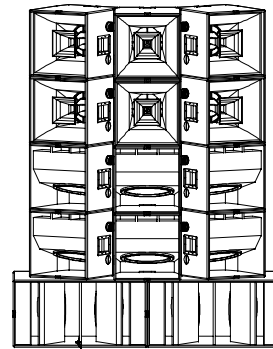
The same system in a flown configuration. This system is suitable for venues or outdoor events up to approximately 2,000 people. Flown systems provide a more even level distribution. Depending on the trim height, the use of additional frontfill systems may be advantageous.
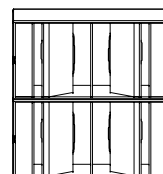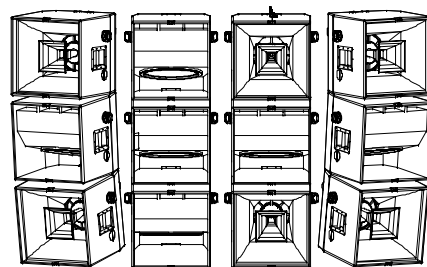
9.3. Example 3:
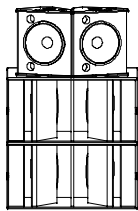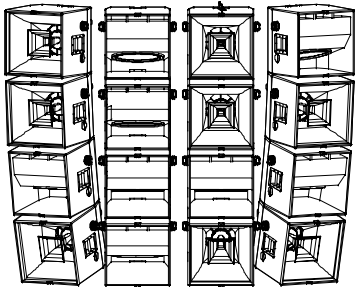
8 x C4-TOP, 8 x C4-SUB, 2 x B2-SUB, 4 x P1200A with mixed C4-TOP/C4-SUB controller modules and 2 x A1 with a B2 controller module.

A frequently used C4 set up for a wide variety of applications. This provides a horizontal coverage of approximately 90° with increased long throw capabilities.

It is a powerful popular music reinforcement system for in or outdoor use. Depending on the actual situation MAX loudspeakers can be added for near field, as shown.

9.4. Example 4:

16 x C4-TOP, 16 x C4-SUB, 4 x B2-SUB, 8 x P1200A with mixed C4-TOP/C4-SUB controller modules and 4 x A1 with a B2 controller module.

This is a 6-wide set up for arenas with side seating tiers and provides 150° of horizontal dispersion. It can be easily adapted to specific situations. The inner columns include long throw and floor coverage. The SUB column is used for increased low frequency throw. The outer columns have decreased directivity to match the shorter distance to side seating tiers. Near field reinforcement is recommended, this could be 2 x C7-TOP (as shown) or 3 x MAX arrayed in a half circle on top of B2-SUBs.
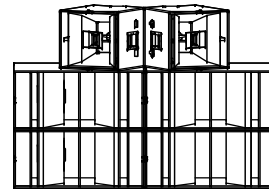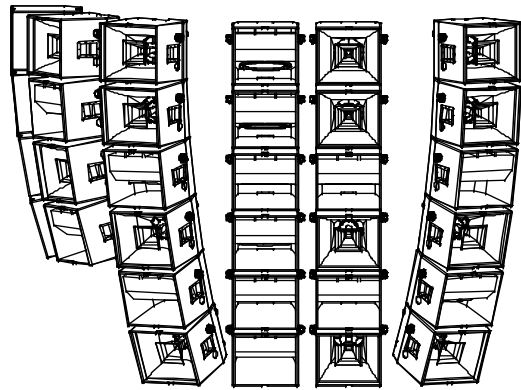
9.5. Example 5:

This example shows a small flown array employing 2 x C3 for the far field (approximately > 25 metres/ 82 ft) with a 40° horizontal dispersion. The C4-TOPs provide an 80° horizontal dispersion in the near field, and 4 x C4-SUBs provide headroom and vertical directivity at lower frequencies. For the total system B2-SUBs and ground stacked near field loudspeakers would be added. This arrangement works well for an audience area that is virtually flat, and provides clear intelligibility and a "close listening" feeling up to approximately 50-60 metres (164-196.9 ft). When less horziontal near field coverage is required the 2 x C4-TOPs could be replaced by a single C7-TOP and another C4-SUB with both columns facing straight forward.

		settings for 2-wide flying system viewed from front of house		R
2-wide Ver. X3.0		1	2	
Main bar	mass/units: kg		507 kg	
	balance (cm)		-3,2	
	detents		6	
Sub bar	detents	11		11
	screw-turns	0,0		0,0
	Column angle (°)	CHAINS:		
	Top box up/downtilt (°)	Len/Angle	0°	30°
	11/--	-2,0°	Copy>	-2,0°
Box Type	1	23/5,35°	C3	SUB
	2	23/5,35°	C3	SUB
	3	23/5,35°	SUB	SUB
	4	22,5/2,5°	TOP	TOP
	5	23/5,35°		
	6	23/5,35°		
	7	23/5,35°		
	8	23		--
Downfill	MAX-MAX			
column	back corner	height.lwst:	4,13m	4,5	4,13m
distance	sides	vert.lowest:	-18,1°	4,3	-18,1°
(cm)	studs	Topchain:	26,4°	4,5	23,2°

Clear · C3 · TOP · SUB · C7 · MAX · HELP

Write DXF · Write EASE 3-file · Write EASE 2/ Ulysses-file

trim height of Pickpoint:	7,5 m =	24,6 ft
dist between rigging-pts. L/R:	15,0 m =	49,2 ft
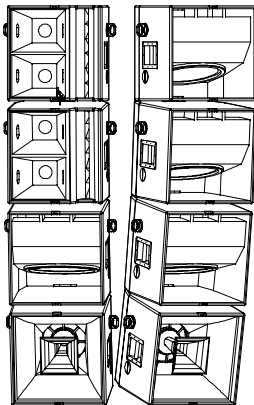
9.6. Example 6:

This 3-wide cluster delivers its main energy to the far field in a 40° horizontal pattern. The central 3 x C3s combine to form a 2 metres (6.56 ft) high line source. The arrangement within both C4-SUB columns produces a higher horizontal directivity pattern, while for the near field the 3 x C4-TOPs produce 100° coverage with adequate headroom. This straightforward high power set up requires a minimum of 2 x B2-SUBs plus additional ground stacked fills, depending on the trim height of the cluster.

		settings for 3-wide flying system view from front of house				Recalc (F9)
3-wide Ver.X3.0				790 kg		
Main bar	mass/units: kg		395 kg		395 kg	
	balance (cm)		8,1			
	detents/distance(cm)	75	20		75	
Sub bar	detents	9	--		9	
	screw-turns	-0,3	--		-0,3	
	Column angle (°)	CHAINS: Len/Angle	-30°	0°	30°	
	Top box up/downtilt (°)		-3,0°	Copy> -3,0°	-3,0°	
Box Type	1	22/0,98°	SUB	C3	SUB	
	2	22,5/2,5°	SUB	C3	SUB	
	3	24/10°	SUB	C3	SUB	
	4	22,5/2,5°	TOP	TOP	TOP	
	5	23/5,35°				
	6	23/5,35°				
	7	23/5,35°				
	8	23				
Downfill	MAX-MAX		--		--	
column	back corner	height.lwst:	5,6m	7,7	5,6m	7,7	5,6m
distance	sides	vert.lowest:		7,6	-16,5°	7,6	-16,5°
(cm)	studs	Topchain:	16,5°	7,2	23,3°	7,2	16,5°

1st Rigg-pt (L) is 0

Clear · C3 · TOP · SUB · C7 · MAX · HELP

Write DXF · Write EASE 3-file · Write EASE 2/ Ulysses-file
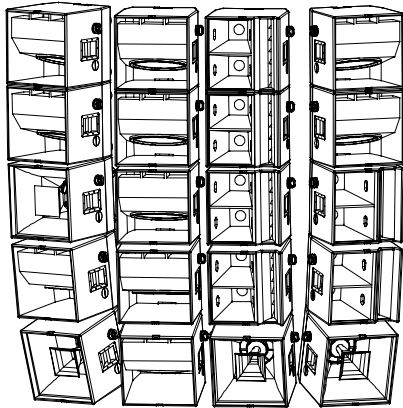
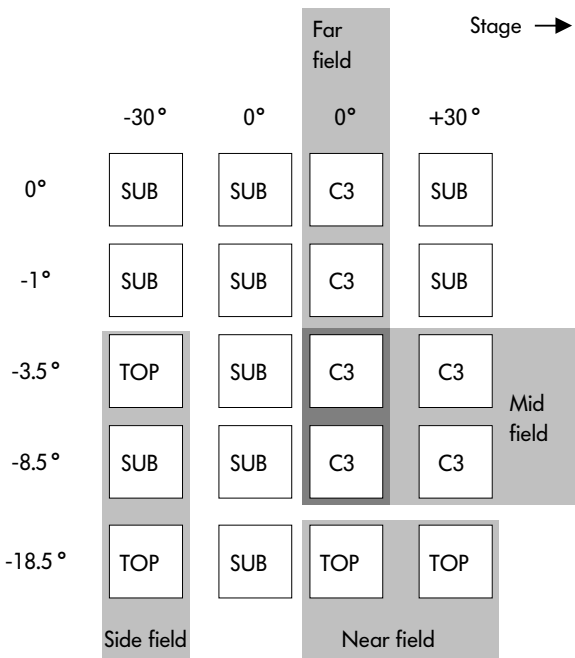|		
trim height of Pickpoint:	9,0 m =	29,5 ft
dist between selected 0-pts. L/R:	22,0 m =	72,2 ft
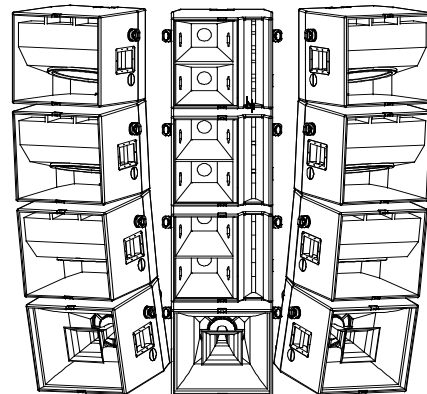
9.7. Example 7:

6 x C3, 4 x C4-TOP and 10 x C4-SUB are used in this medium sized array.

The coverage groups are shown in the picture below.

The far field is covered for low/mid and middle frequencies by the entire centre C3 column. At higher frequencies the upper close coupled C3s provide high frequency coverage in the far field. Increasing the splay between the loudspeakers pointing towards the mid and near field, scales the HF energy according to the distance.

For many venues a horizontal dispersion no more than 40° is advantageous to serve the far field minimizing the amount of reflected energy.

For the mid and near field an increased horizontal dispersion angle is achieved by the two C3 cabinets in the inner column (in rows 3 and 4), covering the mid field and the front of house position. Near field and side field coverage is provided by C4-TOPs, using their 35° vertical dispersion angle to maintain a proper frequency response for those areas.

The C4-SUB arrangement provides the level distribution and power to cope with the C3/C4-TOPs. The SUB column 2 delivers a high vertical directivity, whilst the SUB cabinets in columns 1 and 4 increase the horizontal directivity to the far field.

Two to four ground stacked B2-SUBs and additional ground stacked fills such as C7-TOPs complete the system.
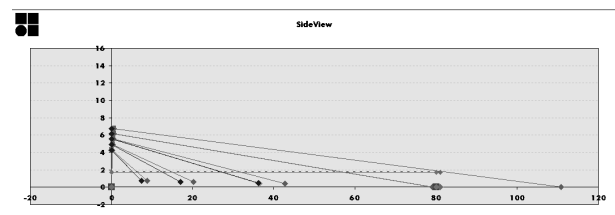
The following TransCalc spreadsheet image shows the rigging details for the above array example.
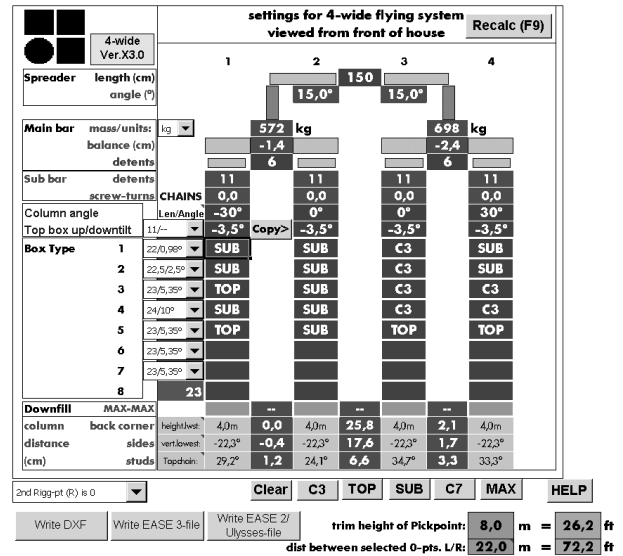

The TransCalc Listening Plane view enables the engineer to exactly define the aiming of the cabinets in the vertical and horizontal. The vertical aiming of the main C3 column just cuts into the listening plane at the farthest point. The cabinets below are set with an increasing splay angle.


The other columns follow in principle the same rules as the main column. Make sure to keep the aiming points of all loudspeakers inside the listening area. This minimizes the reflected energy from the boundary walls. The inner column should not fire across the entire room. This leads to large path length differences between the left and right sources and could cause echoes.
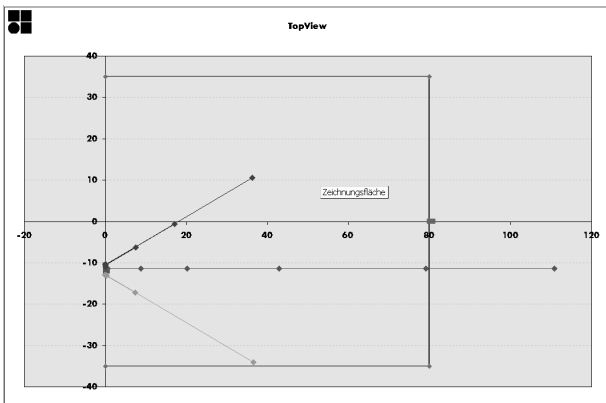
The listening area is 50 x 80 metres (164 x 262.5 ft). This equals an audience of approximately 4,000-6,000, in a medium outdoor area or multipurpose hall. The trim height of the highest cabinet is 7 metres (23 ft). The level distribution was calculated at 1 kHz (0.3 octave bandwidth) including interference due to path length differences. All C3s are driven with the same input level, the near field C4-TOPs are reduced by 3 dB. This results in an even level distribution suitable for popular artists, groups and bands.

If a more even energy distribution is required in the far field for example speech transmission or classical events either the trim height of the cluster, or the number of loudspeakers pointing towards the far field can be adjusted.
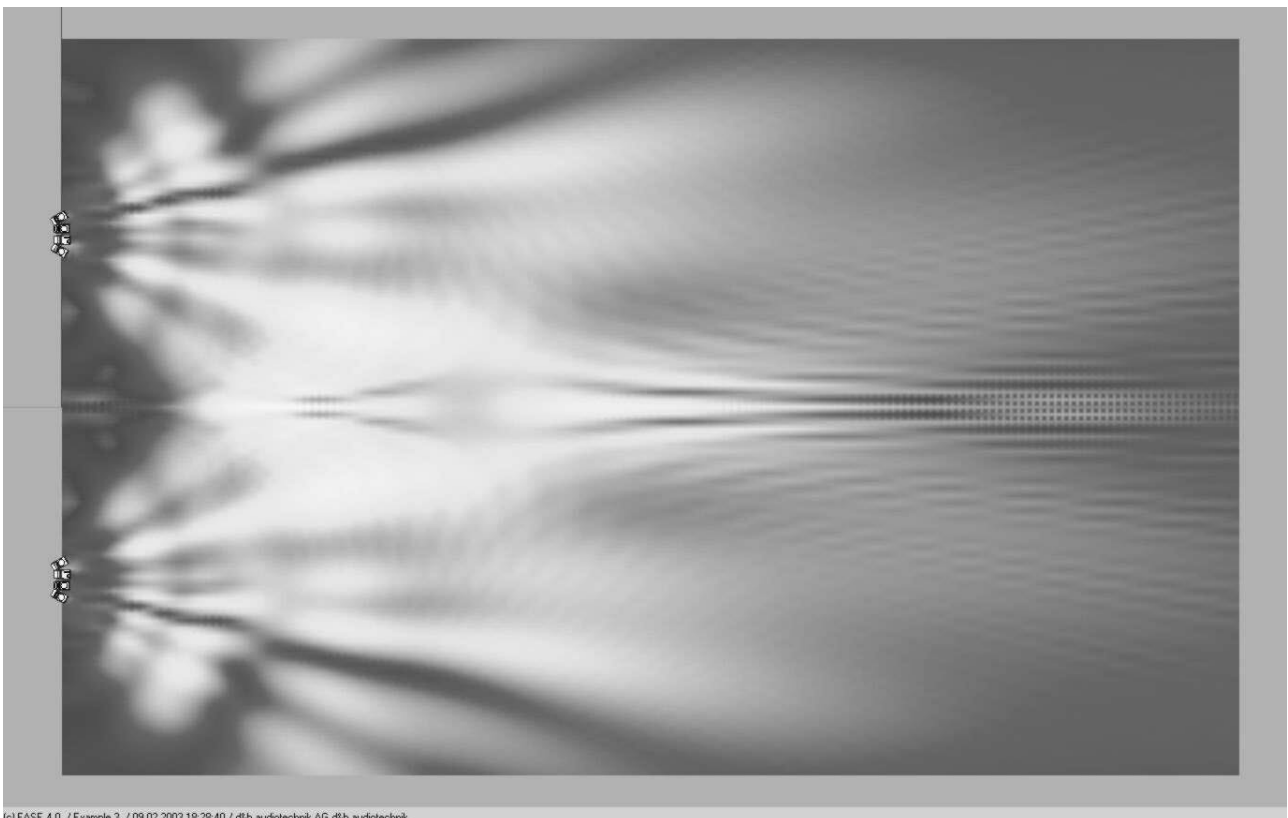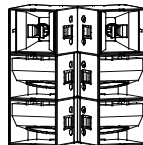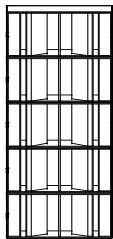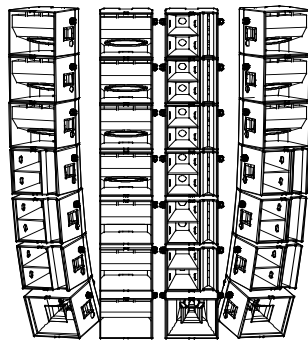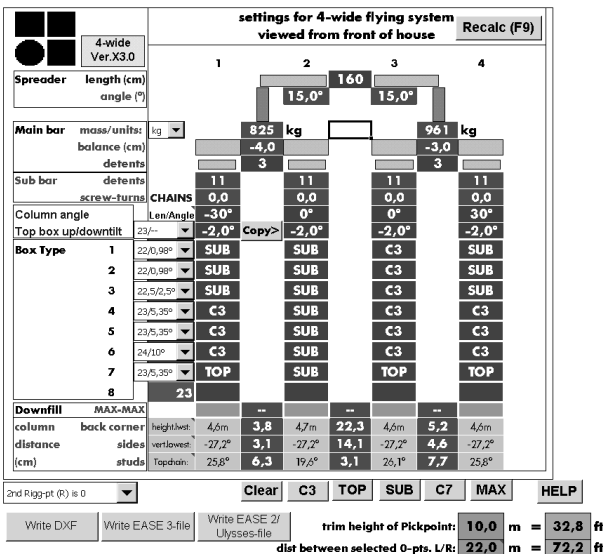

Simulation of the direct sound distribution on a listening area 50 x 80 metres (164 x 262.5 ft)
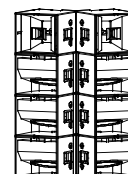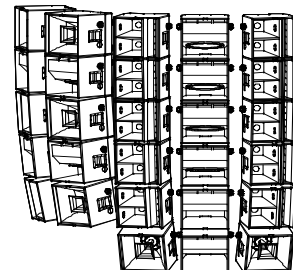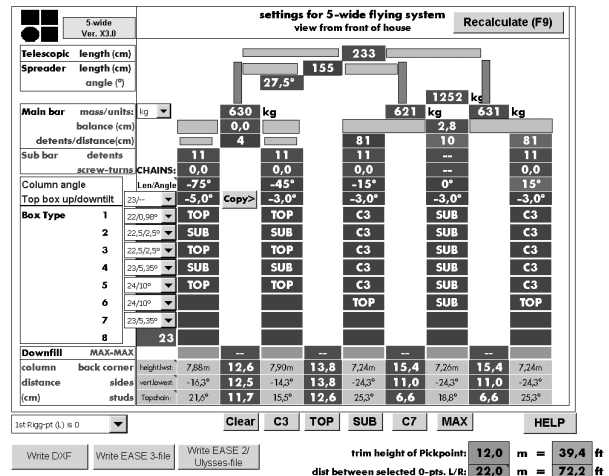
9.8. Example 8:

This 4-wide cluster delivers its main energy to the far field in a 40° horizontal dispersion using the central 6 x C3s. The 3 x 3 C3s in the outer columns supply coverage to the side field, mid field and front of house position. The arrangement of the C4-SUBs couple to supply sufficient headroom while optimizing low end directivity. Ground stacked C7-TOPs produce near field coverage and can be arranged in various combinations with C4-SUBs and B2-SUBs to meet production requirements.

This set up provides sufficient energy with adequate headroom for an audience of 20,000 on a flat field.

settings for 4-wide flying system viewed from front of house — Recalc (F9)

4-wide Ver.X3.0

		1	2	3	4
Spreader	length (cm)		160		
	angle (°)		15,0°	15,0°	
Main bar	mass/units: kg		825 kg		961 kg
	balance (cm)		-4,0		-3,0
	detents		3		3
Sub bar	detents				
	screw-turns CHAINS	11	11	11	11
		0,0	0,0	0,0	0,0
Column angle Len/Angle		-30°	0°	0°	30°
Top box up/downtilt 23/--		-2,0° Copy> -2,0°		-2,0°	-2,0°
Box Type	1	22/0,98°	SUB	SUB	C3	SUB
	2	22/0,98°	SUB	SUB	C3	SUB
	3	22,5/2,5°	SUB	SUB	C3	SUB
	4	23/5,35°	C3	SUB	C3	C3
	5	23/5,35°	C3	SUB	C3	C3
	6	24/10°	C3	SUB	C3	C3
	7	23/5,35°	TOP	SUB	TOP	TOP
	8		23			

Downfill	MAX-MAX		--		--		
column	back corner height/lwst.	4,6m	3,8	4,7m	22,3	4,6m	5,2	4,6m
distance	sides vert.lowest	-27,2°	3,1	-27,2°	14,1	-27,2°	4,6	-27,2°
(cm)	studs Topdchain:	25,8°	6,3	19,6°	3,1	26,1°	7,7	25,8°

2nd Rigg-pt (R) is 0

Clear | C3 | TOP | SUB | C7 | MAX | HELP

Write DXF | Write EASE 3-file | Write EASE 2/Ulysses-file

trim height of Pickpoint: **10,0** m = **32,8** ft
dist between selected 0-pts. L/R: **22,0** m = **72,2** ft
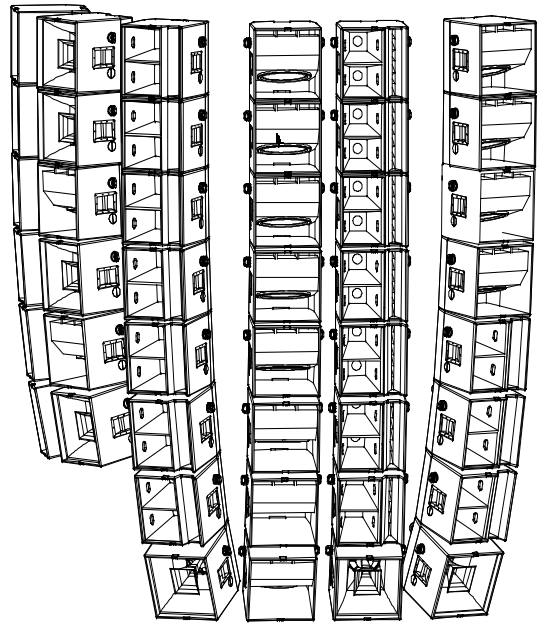

9.9. Example 9:

This example shows a frequently used 5-wide touring set up for a typical indoor arena with 8,000-12,000 seats, the stage set at one end and horseshoe shaped seating tiers. The inner column, on the right of the diagram below points towards the front of house position, which should be a minimum of 30 metres (98.4 ft) from the stage. If the venue has a flat wall instead of rear seating tiers, the signal level of the upper C3s in this column can be reduced to avoid destructive reflections. The centre column that is angled outwards by 15° covers the farthest seating on the side tiers. The outer 2 x 5-deep C4-TOPs and SUBs can be adjusted to provide wide vertical coverage both to the middle of the side seating tiers, and to those side areas adjacent to the stage. The total array can give a 120°-140° horizontal dispersion while two main columns set at ±15° horizontally provide energy into the main audience area. The arrangement of the C4-SUBs couple to supply sufficient headroom while optimizing low end directivity. Ground stacked C7-TOPs produce near field coverage and can be arranged in various combinations with C4-SUBs and B2-SUBs to meet production requirements.

settings for 5-wide flying system view from front of house — Recalculate (F9)

5-wide Ver. X3.0

Telescopic	length (cm)		233		
Spreader	length (cm)		155		
	angle (°)	27,5°			
Main bar	mass/units: kg	630 kg		621 kg	631 kg
	balance (cm)	0,0		2,8	
	detents/distance(cm)	4		81	10	81
Sub bar	detents	11	11	11	--	11
	screw-turns CHAINS	0,0	0,0	0,0	--	0,0
Column angle Len/Angle		-75°	-45°	-15°	0°	15°
Top box up/downtilt 23/--		-5,0° Copy> -3,0°	-3,0°	-3,0°	-3,0°
Box Type	1	22/0,98°	TOP	TOP	C3	SUB	C3
	2	22,5/2,5°	SUB	SUB	C3	SUB	SUB
	3	22,5/2,5°	TOP	TOP	C3	SUB	SUB
	4	23/5,35°	SUB	SUB	C3	SUB	SUB
	5	24/10°	TOP	TOP	C3	SUB	SUB
	6					TOP	SUB	TOP
	7	23/5,35°					
	8		23				

Downfill	MAX-MAX		--		--		
column	back corner height/lwst.	7,88m	12,6	7,90m	13,8	7,24m	15,4	7,26m	15,4	7,24m
distance	sides vert.lowest	-16,3°	12,5	-14,3°	13,8	-24,3°	11,0	-24,3°	11,0	-24,3°
(cm)	studs Topdchain:	21,6°	11,7	15,5°	12,6	25,3°	6,6	18,6°	6,6	25,3°

1st Rigg-pt (L) is 0

Clear | C3 | TOP | SUB | C7 | MAX | HELP

Write DXF | Write EASE 3-file | Write EASE 2/Ulysses-file

trim height of Pickpoint: **12,0** m = **39,4** ft
dist between selected 0-pts. L/R: **22,0** m = **72,2** ft

9.10. Example 10:

This is an example of a system for reinforcing an outdoor stadium show with an audience of approximately 60,000. The 7 x C3s in columns 3 and 5 set at −27° and +3° as shown in the diagram below, deliver the main energy into the mid and far field. The inner column 6 serves the triangle in front of the stage up to a distance of approximately 40 metres (131 ft). The 2 x 6-deep columns 1 and 2 cover the side field, using close coupled C4-TOPs at the top to increase the SPL in the upper listening areas. Exact horizontal aiming angles of the columns depends on the width of the stage and consequent distance between the left and right clusters. The arrangement of the C4-SUBs couple to supply sufficient headroom while optimizing low end directivity. Ground stacked TOP cabinets produce near field coverage and can be arranged in various combinations with C4-SUBs and B2-SUBs. For this example 12 x B2-SUBs per side should produce sufficient low frequency energy.

In terms of energy this set up could throw farther than 100 metres (328 ft) , however thermal, humidity and wind effects can easily ruin the acoustic result at greater distances. Delay systems can be deployed to minimize these disruptive effects over greater distances.

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