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- StepArray -

StepArray column loudspeakers

General Presentation and Principles

Réf : PG-StepArray-0709A.

Contents

1 FOREWORD

This document presents general issues about public address, and introduces the StepArray range.

Chapter 2 briefly introduces the issue of public address in large and reverberant volumes, chapter 3 explains the DGRC principle used by StepArray columns, and chapter 4 is about implementation of StepArray columns.

2 GENERAL ISSUES ON PUBLIC ADDRESS IN LARGE VOLUMES

The quality of speech transmission through an electroacoustic system may be evaluated on several scales :

- **Speech intelligibility**, which characterizes the proportion of words emitted by the PA system and correctly understood by the listener. Intelligibility essentially depends on the signal-to-noise ratio (SNR), the reverberation time (RT), and the ratio (energy of the direct sound) / (energy of the reverberated sound). The latter depends on the loudspeaker-to-listener distance, the number of diffusers and their directivity. Several measurable indices have been proposed to characterize speech intelligibility objectively. The most widely used of them is the Speech Transmission Index (STI). Value 0 corresponds to extremely poor intelligibility, and value 1 corresponds to perfect intelligibility. It is generally considered that intelligibility is correct above STI=0.55, because the meaning of sentences is then understood. There is a “common intelligibility scale” which gives the correspondence between the values of the different indices.

- **Acoustic comfort**. A PA system might provide adequate speech intelligibility while still being juged as rather poor quality. It can be the case if the sound pressure level (SPL) is too high, or if the frequency bandwidth is too narrow, or if the system has high distortion level... In most cases, the area to be addressed is large, and it is desired that the sound level be as constant as possible over the whole listening area. Good acoustic comfort will therefore be obtained with a system that provides homogeneous sound coverage, large frequency bandwidth covering all the human speech spectrum, and low harmonic distortion. In some cases, background noise varies greatly with the occupancy of the room. For example, it is the case in railway stations where the background noise is high during rush hours. The level of the PA system should then automatically be increased in order to keep sufficient SNR.

As can be seen, the most important objective of the PA system is to provide a **strong and constant direct sound** over all the audience area, and minimize the energy emitted elsewhere (as is feeds the reverberation) as explained on figure 1.

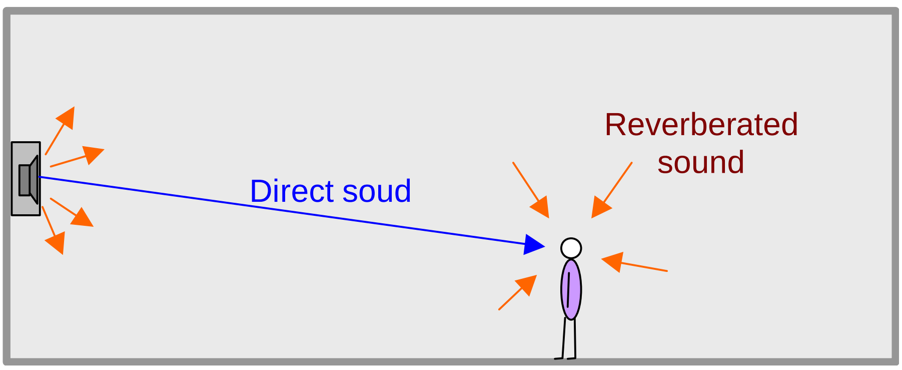


Figure 1 : Direct sound increases speech intelligibility, reverberated sound impairs it.

Speech intelligibility eventually decreases when increasing the number of diffusers. It is usually desirable to use as few diffusers as possible. In addition to improved acoustic performance and reduced cost, it minimized the **aesthetical impact** of the PA system (diffusers and cables).

In some cases, the PA system is also in charge of diffusing security messages. The system must then meet standard EN60849 which specifies a minimum intelligibility level, and also requires the system to check correct system operation (processor, amplifier and loudspeakers), and inform the user in case of system dysfunction. We talk about **Sound Security Systems** (SSS).

3 LOUDSPEAKER ARRAYS

3.1 Introduction

In the previous paragraph, we have seen that we want a diffuser which provides strong and constant direct sound over all the audience area. Arrays of loudspeakers are often the best solution to achieve this goal. Indeed, although a distributed PA system might yield a relatively constant SPL over the audience using a large number of loudspeakers, it is usually not able to provide satisfactory speech intelligibility when the reverberation in the room is high. In addition, it has generally a rather negative impact of the visual aspect of the room. As opposed to that, high speech intelligibility can be obtained with a limited number of loudspeaker arrays (often only 1 or 2) in a large and highly reverberant room ; with minimum impact on the aesthetics of the room.

It is rather easy to calculate the shape of the wave front that should be radiated by a loudspeaker array in order to yield constant SPL over all the audience area, and minimize sound energy emitted elsewhere. We then obtain a *J* shape for the wave front, in which the local curvature depends on the focal distance, as illustrated on figure 2. In order to generate such a wave front shape, one can align loudspeakers along the *J* shape as in **geometric arrays** (figure 3) [3], or place loudspeakers on a vertical line and rely on the filtering of each individual loudspeaker as in **electronic arrays** (figure 4) [4]. The latter case corresponds to column loudspeakers, which can be flush mounted on a wall. Advantages and disadvantages of both array types is discussed in [2].

The main characteristic of an array is its **range**, which corresponds to the minimum and maximum distance (from the column) where the SPL is constant (with a given tolerance). The highest the column, the longest the range. Another important characteristic of an array is the spacing between loudspeakers. Good rejection of secondary lobes at high frequencies is obtained with a short spacing. At high frequencies, geometric arrays generally uses waveguides that radiates like an isophase vertical slit. Aligning several of these waveguides yield a quasi continuous “line source”, which greatly reduces undesired secondary lobes.

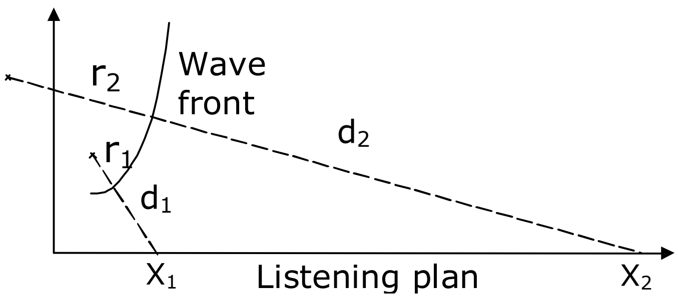


Figure 2 : J shape wave front required in order to radiate constant SPL over the listening plan.

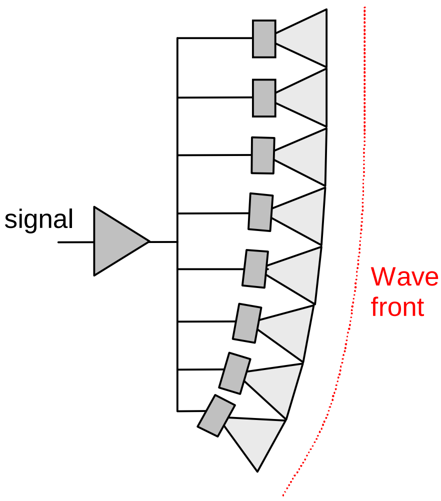


Figure 3 : In a geometric array, loudspeakers are aligned along the shape of the wave front to be generated, usually a J shape.

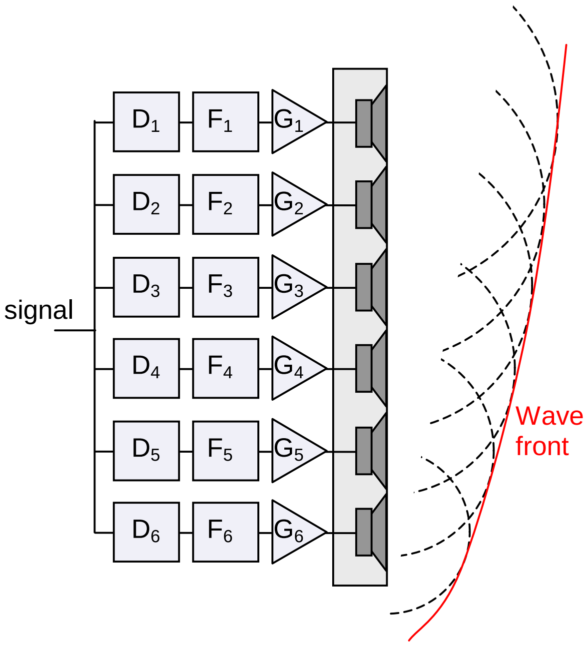
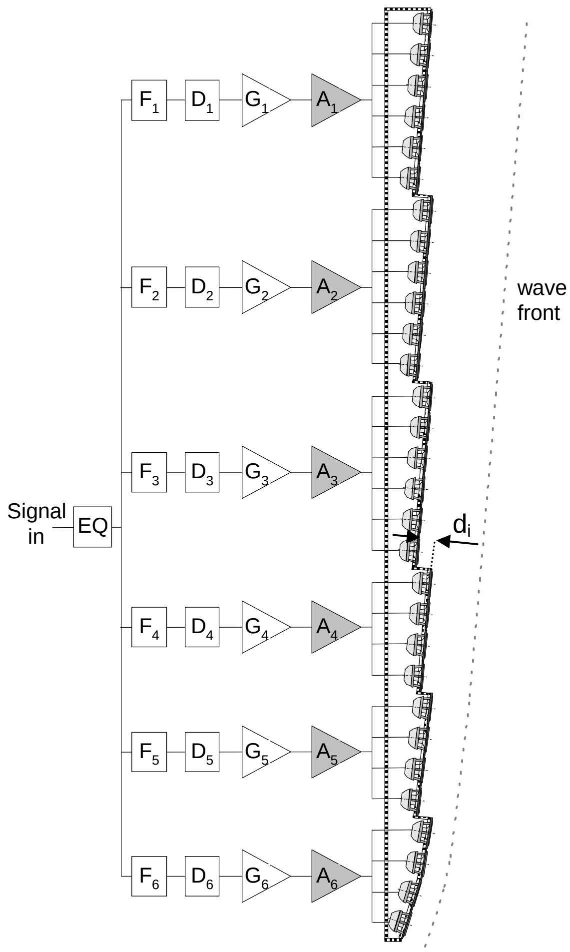


Figure 4 : In an electronic array, loudspeakers are aligned vertically, and the wave front is synthesized by adequate filtering by delays D_i, filters F_i, and gains G_i associated to each loudspeaker.

3.2 The DGRC principle and the StepArray columns

Active Audio has introduced a new array principle, named DGRC (Digital and Geometric Radiation Control), which can be seen as a synthesis of geometric and electronic loudspeaker arrays (Active Audio patent [1]). The DGRC principle is illustrated on figure 5. The idea is simply to chop the desired wave front shape into sections and move them back on a vertical line, much like what is done in the Fresnel lenses used in optics. Then the DSP basically just has to perform the delays corresponding to propagation over distance d_i between the sections. The saw-tooth profile is characteristic of the DRGC array principle. We have shown [2] that with this delay setting there is no diffraction at edges of the saw-tooth shape. As a result of this principle, the number of DSP and amplification channel is independent of the number of loudspeakers, so that a dramatically reduced number of channel is achieved.



<u>Figure 5</u> : The DGRC principle used in StepArray columns. The wave front is controlled both by the positioning and orientations of the loudspeakers, and by the delays D_i, filters F_i and gains G_i of each channel.

With the StepArray columns, we usually obtain on a horizontal listening plan :

Range ≈ 12 x height of the column

For example, a 2.5 m high column has a range of 30 m.

Here the range is defined as the distance interval within which the SPL (averaged over the 500Hz to 4kHz octaves) doesn't vary by more than 6dB (±3dB).

- Main advantages of the DGRC principle used in StepArray columns are :
- The number of electronic channels (DSP & amps) is dramatically reduced. For example, model SA250P, which is 2.5 m high and has a section of 124x150mm, only uses 6 channels for 30 loudspeakers. This yields a large cost reduction.
- The number of channels doesn't depend on the number of loudspeakers. As a consequence, a large number of small wide-band loudspeakers may be used to obtain a high quality restitution of the mid- and high frequencies, and minimum secondary lobes.
- Power is uniformly distributed upon loudspeakers, so that their individual responses match better. In addition, they can all be driven at their maximum, so that the max SPL is optimized.
- The DGRC principle is applicable to line sources used in high power sound reinforcement systems. The mechanical hanging system is then greatly simplified, and the directivity can be easily adjusted with the DSP .

The main limitation of the DGRC principle is :
- The number of DSP channels being limited, there is less flexibility on the control of directivity than there would be with one DSP channel per loudspeaker. For example, it is not possible with a DGRC array to generate several main lobes. However, DGRC arrays are essentially dedicated to the usual case where the column is vertical and the the audience is situated on a plane, generally horizontal.

StepArray columns use **external electronics,** consisting in a UT26-SA processor, and a multichannel power amplifier. In addition to the advantages inherent to the DGRC principle listed above, the fact of having an external electronics has the following advantages :
- Possibility of associating several columns to a single UT26-SA processor, yielding a large cost reduction (see § 4.3).
- Possibility of using several amplifiers on a column in order to increase security : failure of one amplifier only affects some of the channels, but the column continues to diffuse messages. For example, when using 2 columns and 2 amplifiers, amplifier 1 can be connected to channels 1, 3, 5 of both columns, and amplifier 2 to channels 2, 4, 6 of both columns.
- Maintenance is easier.

UT26-SA DSP processors feature filtering functions such as the control of directivity, equalization, delay, and high level functions which are briefly introduced in § 4.1.

3.3 Modeling loudspeaker arrays

There are powerful CAD software tools that can predict the acoustics of a room, and accurately model the radiation of loudspeaker arrays. These tools can calculate various acoustic indices, such as the reverberation time, the sound pressure level, the STI…

All loudspeakers of an array are operating in a coherent way, as opposed to the loudspeakers of a distributed PA system. The coherence of the loudspeaker array must be taken into account in the modeling. To do so, we propose software modules (DLL) which enables the CAD tools to model properly the StepArray columns.

Figure 6 shows an example of a modeling result obtained with a column SA250P in a large room having a mid-frequency RT of 3.3 sec. One can notice the homogeneity of the SPL and the good STI value.

With the StepArray DLLs, one can adjust the column directivity parameters as can be done in real situation with the SAdrive control software.

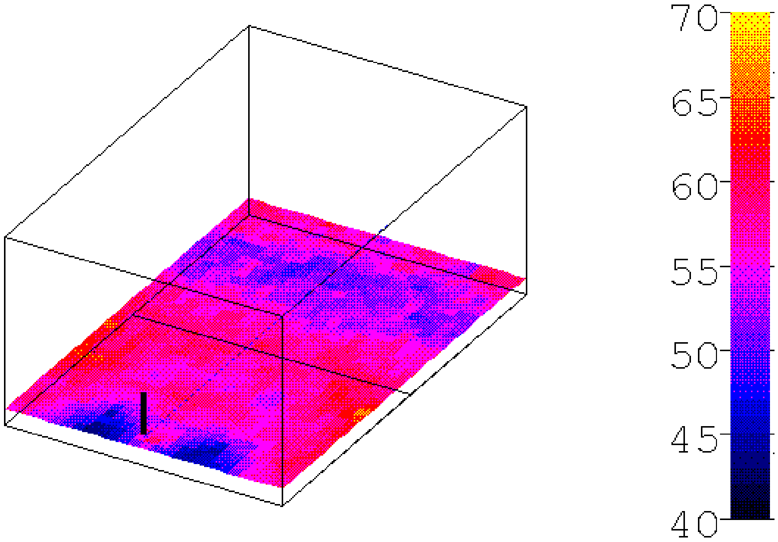


Figure 6 : Example of RASTI modeling using software Catt®.
The room dimensions are 38x25x17 m, and its RT is 3.3 seconds at 1kHz.
A SA250P column is placed at 2.6 m from the floor, and the listening plan is 1.6 m above the floor.

4 THE STEPARRAY RANGE

4.1 Introduction

We have seen that the electronics of the StepArray column is outside the column, usually with the rest of the audio equipment. The column is passive. We have listed the main advantages that result from this strategy, in particular the fact that several columns can be associated to the same processor, and sometimes the same amplifier.

The StepArray range features mainly :

- column loudspeakers
- audio processors UT26-SA
- multichannel power amplifiers
- control PC software SAdrive

In addition, there are a list of options :

- MIC Option : the column is equipped with an electret microphone, and analog input 2 of the UT26-SA has a preamp and phantom supply for the microphone. With this option, a new function is available.
  The AGC function (Automatic Gain Control) provides automatic adjustment of the level of level of diffusion according to the background noise captured by the microphone. In a railway station for example, diffusion level should be minimum when the station is quiet, and maximum during rush hours.
- SUB Option : an additional analog symmetrical output is provided on the BCL connector of the UT26-SA processor in order to connect a sub-woofer. This option is intended for installations dedicated to music diffusion.
- COL Option : StepArray columns may be painted in a specific RAL color specified by the client.
- CV232 Option : with this option, processor UT26-SA can be connected directly to the RS232 serial port of a PC. However, if the distance between the PC and the UT26-SA exceeds 25 m, it is recommended to transmit command signals in the RS485 format, in which case the PC should be equipped with an RS485 port and connected to the BAN port of the UT26-SA (see the Technical Manual of the UT26).
- SSS Option : the UT26-SA processor is equipped with a device which detects failure of the amplifier and the loudspeakers, in accordance with standard EN-608498 for Sound Security Systems (SSS). Occurrence of a failure results in the opening of a contact on the BCL port of the UT26-SA. This option will be available at the end of 2006.

SAdrive is a powerful and user-friendly PC software for both the installation technician and the exploitation technician. It can handle up to 254 UT26-SA processors connected to StepArray columns, adjust all filtering parameters, save / recall presets, perform **maintenance via Internet**,… Note that **SAdrive is not necessary for using the columns**. Once installation technician has saved the filtering parameters in the permanent (flash) memory of the DSPs, the processors – and hence the columns – can operate without SAdrive.

4.2 The catalogue

Reference	Description
SA100P	Column loudspeaker ; height 1 m ; range 15 m (+/-3dB) ; for flat audience ; 3 channels.
SA180P	Column loudspeaker ; height 1,8 m ; range 30m (+/-3dB) ; for flat audience ; 3 channels.
SA250P	Column loudspeaker ; height 2.5 m ; range 35 m (+/-3dB); for horizontal audience ; 6 channels.
SA250S	Column loudspeaker ; height 2.5 m ; range 26 m (+/-3dB) ; for tilted audience ; 6 channels
Option COL	Specific RAL color.
Option MIC	Microphone in the column, preamp in the UT26-SA, for functions AGC
UT26-SA	Digital audio processor with software for StepArray columns (6 sorties)
Option SUB	Output for sub-woofer on UT26
Option CV232	RS485/RS232 converter for connecting to a RS232 port of a PC.
Option SSS	Detection of amplifier and loudspeaker failures, in accordance with standard EN-60849.
MPA6150	Amplifier 6x100W / 8Ω, 150W / 4 Ω.
SAdrive	PC Software for tuning and exploitation of a StepArray system.
FC2250	Flight-case for transport of StepArray columns.

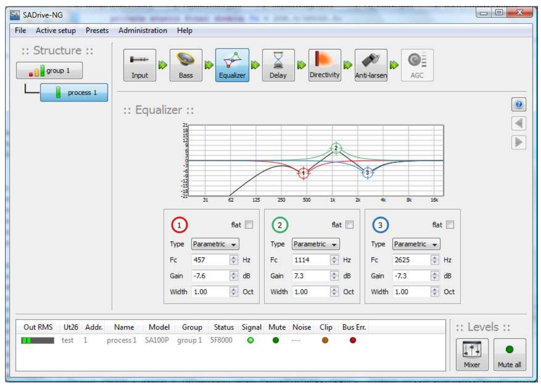
SA250P
SA250S

SA180P

SA100P

Processor UT26-SA

Amplifier MPA6150



SAdrive 2 Software

4.3 Associating several columns

Associating several columns to a single processor

A UT26-SA processor may be connected to several StepArray columns (via amplifiers). In this case, it is clear that filtering DSP parameters will be the same for all the columns. It is therefore necessary that the column be compatible. It is always possible to connect an unlimited number of columns of the same type on the same processor. In addition, some columns of different types may still be compatible. For example, there is no problem connecting one (or several) SA250P column and one (or several) SA100P column to the same UT26-SA processor (via amplifiers), because the positioning and orientations of the loudspeakers of the SA100P column are identical to those of the 3 bottom channels of the SA250P column.
For details about column compatibility, please refer to the technical data of each column.
Figure 7 illustrates how to connect 2 amplifiers on a single UT26-SA processor.

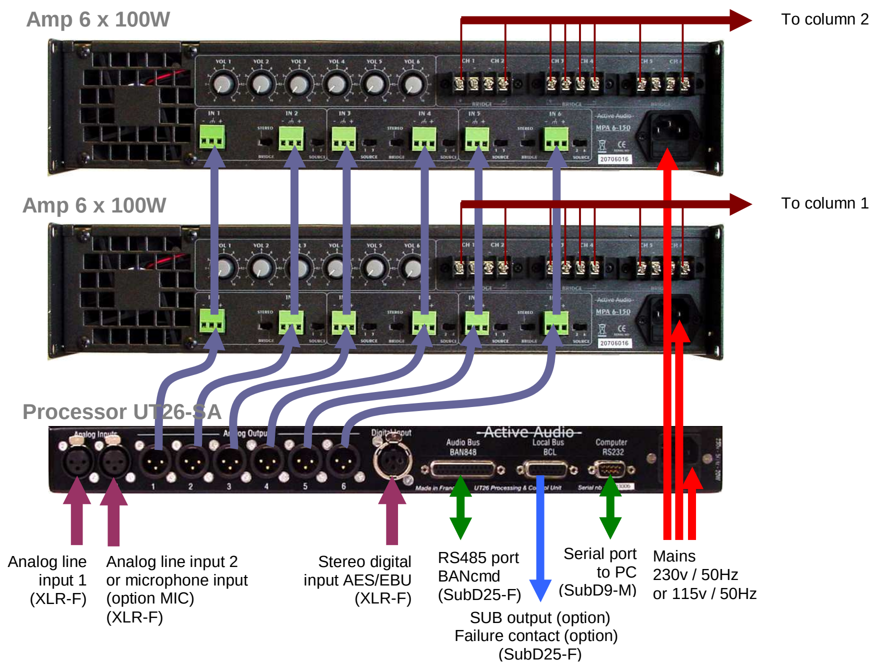


Figure 7 : Association of 2 amplifiers / columns to a single UT26-SA processor.

Case of the MIC option : If the UT26-SA processor is equipped with the microphone input and connected to several columns, each having a microphone, then only one microphone should be connected to the microphone input.

Associating several columns to a single amplifier.

Processors UT26-SA have 6 analog outputs connected to the 6 inputs of a 6 channel amplifier (e.g. MPA6150). Some columns have 6 channels, but others only have 3, like the SA100P or SA180P columns. It is then possible to connect 4 SA100P and/or SA180P columns to the same amplifier (figure 8).

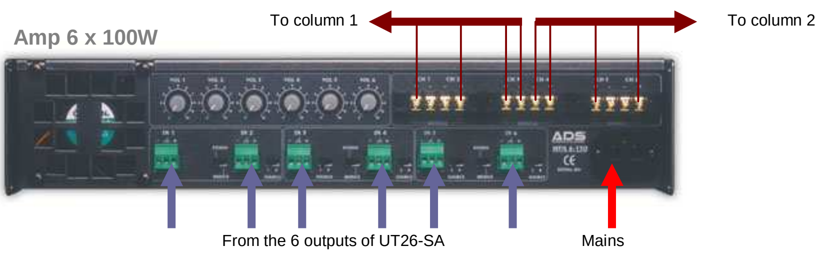


Figure 8 : Associating two 3 channel columns to a single 6 channel amplifier.

Note that it might be interesting to mix the channels from two amplifiers : for example, connection of two MPA6150 amps to two SA250P columns may be done by affecting channels 1, 2, 3 of each amp to column 1, and channels 4, 5, 6 of each amps to column 2. With this cabling scheme, both columns continue to work (in a reduced mode) in case of failure of one amplifier (figure 9).

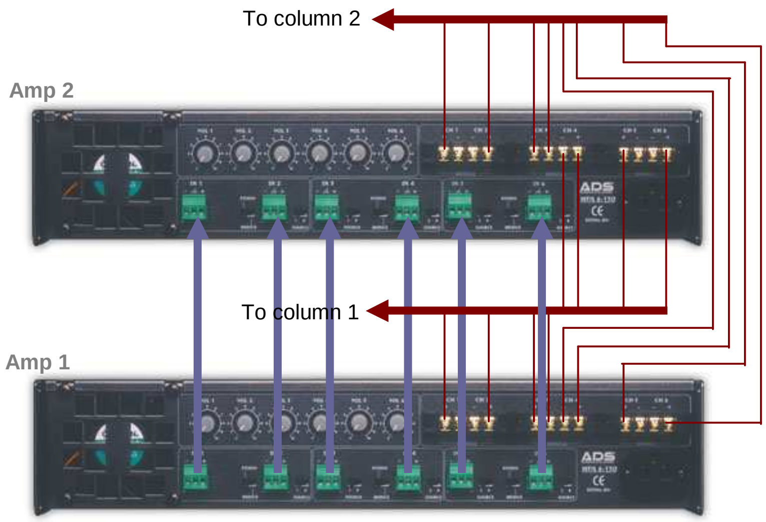


Figure 9 : Mixing the outputs of two amplifiers to two columns.
Column 1 use channels 1, 2, 3 of amplifier 1, and channels 4, 5, 6 of amplifier 2 ;
Column 1 use channels 1, 2, 3 of amplifier 2, and channels 4, 5, 6 of amplifier 1.

4.4 About the amplifier and cabling

Each channel of a StepArray column comprises 4 to 9 loudspeakers.
In model SA250P column, 3 out of the 6 channels have 4 loudspeakers, the other 3 have 6 loudspeakers. Model SA100P has only 3 channels, each consisting of 4 loudspeakers.
The nominal impedance of each channel depends on the number of loudspeakers : 8 Ω for 4 lps, 5.33 Ω for 6 lps, and 8 Ω for 9 lps.
For models that only have 4 or 6 lps channels, we recommend using a 6x100W/8Ω / 6x150W/4Ω amplifier such as the MPA6150. With such an amplifier, permanent SPL of over 95dBSPL can be obtained, which is usually more than enough.

However, there is no problem using another type of amplifier, as long as it has the required power, accepts the loudspeaker channel impedance, and that the voltage gain is identical for all 6 channels.

Careful attention should be paid at cabling : the diameter of the wires should be such that the resistance (hot and ground) does not exceed a limit (see the manual of the columns).

5 OTHER TEHCNICAL DOCUMENTS

- SAdrive User Manual
- Technical Manuals of StepArray columns
- Technical Manual of processor UT26

Can be downloaded from our web site www.activeaudio.fr.

6 LITERATURE

[1] « Dispositif de sonorisation à contrôle de rayonnement géométrique et électronique », Brevet FR-0403052, inventor X. Meynial, déposé le 25 mars 2004.
See also PCT FR05-00597.

[2] X. Meynial, « DGRC arrays : A synthesis of geometric and electronic loudspeaker arrays », AES 120th Convention. Preprint 6786, Paris May 2006.

[3] « Sound Wave Guide », US Patent # 5,163,167, Inventor : C. Heil, nov 10 1992.

[4] G.W.J. van Beuningen; E.W. Start; Optimizing Directivity Properties of DSP Controlled Loudspeaker Arrays, Reproduced Sound 16 Conference, Stratford (UK) 17-19 Nov 2000, Institute of Acoustics.