# Adaptable

## Stoll Audio Convertible PA-System at Kulturfabrik Kofmehl in Solothurn

*Dieter Michel*

**Nowadays, most medium-sized to large PA tasks in halls and open-air are tackled with line arrays. The technology has gained acceptance. So, for us it is no problem to cover events where line arrays are used. Of course, it is even more interesting when it is not just about a use-case of line arrays, but also about new technologies. We had such an opportunity on 9 May in the Swiss town of Solothurn in the shape of a concert of the Dutch saxophonist and singer Candy Dulfer, who was appearing there with her band at the Kulturfabrik Kofmehl. The concert was run on the house system, which is based on 2x6 elements of the Convertible PA system and accompanying sub-basses from the Swiss manufacturer Stoll Audio. What is special about the convertible system is that you can switch the loudspeaker components between the modes "line array" and "point source" inorder to get the optimal radiation pattern for the respective sound task.**

### Kofmehl cultural centre

The Kulturfabrik Kofmehl is organised as a non-profit association and is run largely with volunteer work. A total of around 250 employees perform the tasks that arise, which, among other things, also offers the young volunteers the possibility to gather experience in organisation and the operation of a self-supporting company. The Kulturfabrik Kofmehl actually emerged from an initiative by young people who staged a play in the former factory building of "Otto Kofmehl Metallwaren AG" out of a lack of other opportunities of cultural production. Over time, a regular workshop arose from this activity, for which the association „Zwischenraum" was founded.

Now, they no longer use the old factory hall, but instead a new building not far from the old location, the construction of which was funded largely by donations. This new building was opened in April 2005. The new site now receives more than 75,000 visitors per year, making the Kulturfabrik Kofmehl one of the most popular concert locations in Switzerland. Dominik Stoll provided constructional-acoustic advice for the new building on the green meadow.

### Sound situation/room acoustics

The Kulturfabrik Kofmehl possesses two function rooms with stage, namely the concert hall with a capacity of around 900 people, and the smaller "Raumbar", with capacity for around 200 people, which is also suitable for readings, cabaret events and the like.

The concert hall has basic dimensions of around 20m x 13m, with the stage accounting for around 5m of the room depth. The hall, with sturdy brickwork, stands on a separate foundation from the rest of the building for soundproofing reasons, to minimise sound emissions into the area around the Kulturfabrik with this "room-in-room" construction.

In the hall, the audience is spread over two levels and has room on the first upper floor on a gallery running all the way around ("estrade"). Sound has to be delivered to both areas, although in the

rear area of the hall at ground floor level, beneath the gallery, there is a bar where a somewhat lower direct sound level is desired in order to allow conversations. On the gallery there are several tribune-style structures for standing places. This way the audience is staggered in height from the ground floor level up to the top tribune seat. Accordingly, this area of the audience must also be acoustically covered throughout its height.


## Sound concept

A type CFR2610 Convertible public address system from the Swiss manufacturer Stoll Audio from Basel is used to fill the concert hall of the Kulturfabrik Kofmehl with sound. To the left and right of the stage, two relatively low-hanging arrays are operated, each consisting of six CFR2610, which are relatively slightly curved. Each CFR2610 module is 58cm high, accordingly giving an array length of around 3.60m. Although, with a lower frequency limit of 60Hz ( 3dB) (40 Hz -6 dB in step-down mode, the systems are fundamentally full-range-capable. For music with some emphasis on loudness, which is certainly part of the Kulturfabrik's events profile, it is nevertheless a good idea to supplement them with suitable sub-basses. In the Kofmehl, two Stoll IL3500 Infralow sub-basses are used for this purpose and are positioned below the stage. More about this later.

In many other line-array applications, the arrays are often more curved to cover a larger vertical angular range - especially the close range in front of the stage.
According to Dominik Stoll, however, founder and chief developer of Stoll Audio, this often works better visually than acoustically. If the array elements are angled against each other, then the vertical nominal dispersion angle in the high-frequency range is larger in total, provided that you do not overdo it with the angling so that the high-frequency systems no longer work as a continuous line array speaker. If this occurs, the high-frequency emission breaks up into individual sources, and you again get undesirable interference effects in the transitional area between the individual array elements. Even if this does not happen, the vertical emission behaviour will not spread out in the medium range in the same way as in the high-frequency range, because, due to the larger wavelengths, the curving - or deviation from a straight line - is not big enough to be effective. The emission behaviour in the medium range then continues to be dominated by the total length of the array, so that in the end deviations in the sound balance can arise depending on the listening position. Dominik Stoll therefore recommends only curving a line array of convertible elements very little and using another additional element in point source mode angled as the lowest element - as a sort of front-fill.

## Stoll Convertible functional principles

Apropos: What does the term "point-source mode" mean, anyway?
As the name already says, the Stoll CFR 2610 Convertible loudspeaker system is convertible, namely between the modes point source and line array. These two variants represent, so to speak, the two essential, fundamental modes in which the majority of professional PA systems are operated these days.
Of course the idea of building a convertible sound system has the aim, among other things, of creating loudspeakers

*View of the stage in the concert hall*


that are suitable for both modes and thus universally usable. For rental operation this of course means that the loudspeakers do not have to stand in the store because, for example, they are not technically suitable for a particular type of application. Instead, they are meant to make it possible to adapt them to the type of application through the choice of mode, in a simple way, without complicated alterations to the loudspeakers.

### Back then ...

Up to the beginning of the nineties, the point source mode was a kind of ideal goal for loudspeaker developers. Technically, it is of course very difficult to build a genuinely spherical loudspeaker that could emit in all directions, unless someone managed to construct the loudspeaker in such a way that it would be substantially smaller than the wavelength of the emitted sound in all (!) useful frequency ranges. Firstly, this is not exactly simple and secondly, neither is it desirable for a professional sound system in most applications.

Instead, what is generally aimed for is a loudspeaker system that covers the audience and/or listening areas as evenly as possible, but at the same time emits as little sound as possible into areas outside of these. In the majority of loudspeaker designs, the chosen means is a constant-directivity horn for medium and high frequencies, which ensures – or is meant to ensure – the desired defined sound emission in its scope. In the lower frequencies, a cone loudspeaker normally takes over, which – depending on its size – starts to beam in the mid range due to it's membrane size. Normally, the attempt is made to adapt these bundling characteristics to the horn's emission characteristics to give the smoothest possible transition. The directivity of such speaker systems decreases towards low frequencies, because the emitting area is no longer big enough in comparison with the wavelength.
The problem with this design is that as soon as the desired audience area can no longer be covered with an individual loudspeaker box, the question arises as to how the emission area can be extended with additional loudspeaker systems.

The typical approach here has been to form so-called clusters or arrays in which several loudspeaker boxes are lined up side by side (sometimes also head to head, which is to say horn to horn), in the hope that one can then use the combined dispersion areas of both loudspeakers.
The problem, however, is that the loudspeaker boxes cannot be lined up in such a way that their acoustic centres - which is to say the points from which the emitted wave field is apparently sent out - are brought into alignment. That is not possible because the loudspeaker components such as horn driver and cone chassis cannot overlap mechanically, not to mention the fact that they are housed in different boxes.
In practice, then, this means that two or more sound sources next to each other are emitting the same signal, which may lead to unwanted interference, at least in the transition bet-

ween the two dispersion areas. In actual fact, a major aim in the development of array-capable point sources was to suppress such interference effects in the crossover ranges as effectively as possible.
At the start of the nineties, in an AES paper, the French physicist Christian Heil put forward the suggestion of building up PA systems according to the principle of the line array speaker [1]. Such a PA system should be composed of individual elements that should fulfil certain acoustic criteria. If this could be ensured in the design, it would be possible to use many such elements to assemble an array several to many meters long, which would behave acoustically like a single line array speaker. This would have had the invaluable advantage that one would not have to worry about any interference effects in the direction of the line, which is to say in the vertical in the case of a vertically hanging line array.

Because of the great length of the line array speaker, however, it would exhibit a very strong directivity, especially in the high-frequency range, which would make it necessary to handle such a PA system in a special way. The first large line-array PA systems that Christian Heil launched on the market with the company he founded, L-Acoustics, were therefore only rented with an operator.

### ... Today

In the 25 years since their market launch, large line-array PA systems have become firmly established in the product ranges of most loudspeaker manufacturers and are often almost regarded as a panacea for all kinds of PA tasks. They can indeed very often show their advantages, especially that of being able to evenly cover large arenas or outdoor venues with two or four very slim loudspeaker arrays, without the loudspeaker systems themselves being too visually prominent.

Line arrays are not always the best solution for each and every PA task, however, which means that there is still definitely a place for point sources. This brings

*Rear part of the concert hall with view of the gallery and tribune constructions*

us back to the Convertible system from Stoll Audio: If a loudspeaker system allows you to choose, you do not have to commit yourself from the beginning.

### CFR2610 Convertible

From it's outward appearance, a single CFR2610 Convertible loudspeaker is not very different from a classic 15/2 loudspeaker system at first glance.
Designed in a rather upright format, with dimensions of 580mm x 490mm x 377mm - with a trapezoidal housing outline and side walls slanting at 45° in the rear area, for monitor use for example, and a steel front grill - the housing actually has a rather classic look. For the user, this of course has the advantage that handling is familiar and convenient and goes off without problems. So it is probably going to be more “what’s inside” that makes it different from the usual PA systems of other manufacturers.

You get an initial indication of this when you look at the back panel of the box with its somewhat unusual connection design. In a kind of bay on the rear of the housing there are two metal housings with Speakon connections and a multi-

*The FOH position on the ground-floor level in front of the staircase*

*Rack cabinet with the audio electronics for the sound system in the Kulturfabrik Kofmehl. The upper group of four in the rack are the Lab.Gruppen amplifiers for the Stoll Convertible arrays.*

pin connector. These are the so-called transfer modules. They establish a connection between the output channels of the power amp and the individual loudspeaker components with which the CFR2610 is equipped.

Each single chassis is individually wired to this multi-pin connector, which enables the transfer module to connect the internal loudspeaker components to the power amp channels differently according to the respective mode - point source or line array. Therefore there is one transfer module for the point source mode and one for the line array mode. Only one of these is active at any one time and inserted in the multi-pin connector of the boxes, the other is locked in a kind of parking position so that it is ready to hand if needed. In addition, there is an extender module that only drives the woofers, in the event that additional low-frequency performance is required within the array.

This sounds complicated at first, but is essentially very simple if one takes a closer look at the transducer assembly:
A total of ten 5" high-performance chassis are built into a CFR2610 as well as - and this is a special feature - two different high-frequency systems optimised for the operation of the loudspeaker as a point source or line array element respectively. It is certainly quite exceptional that the developer has provided two dedicated high-frequency systems here, one for each mode, with easy electrical switching from one to the other. At least I'm not aware of another manufacturer that does this in the same way.

Another concept, however, that has been seen before elesewhere is to arrange the high-frequency part of the system in such a way that the HF subsystem can be changed/replaced with little effort, so that an HF unit suitable for the respective mode can be installed. This, however, requires a modification of the box each time the mode is changed and can therefore not be accomplished in a few seconds.

## Acoustic pixel technology

In the CFR2610, the ten 5" chassis are arranged in a kind of matrix in three vertical columns, as shown in the graphic above on this page.
The two outer columns are each equipped with four chassis, the middle one with two chassis. The acoustic characteristics of these 10 chassis as a whole varies depending on their wiring and selection. Due to the longer wavelength of the frequency range that they emit, the drivers, mounted close together, in both modes or control variants, form a coherent sound source with the desired emission characteristics. Stoll Audio named this concept Acoustic Pixel Technology (APT).

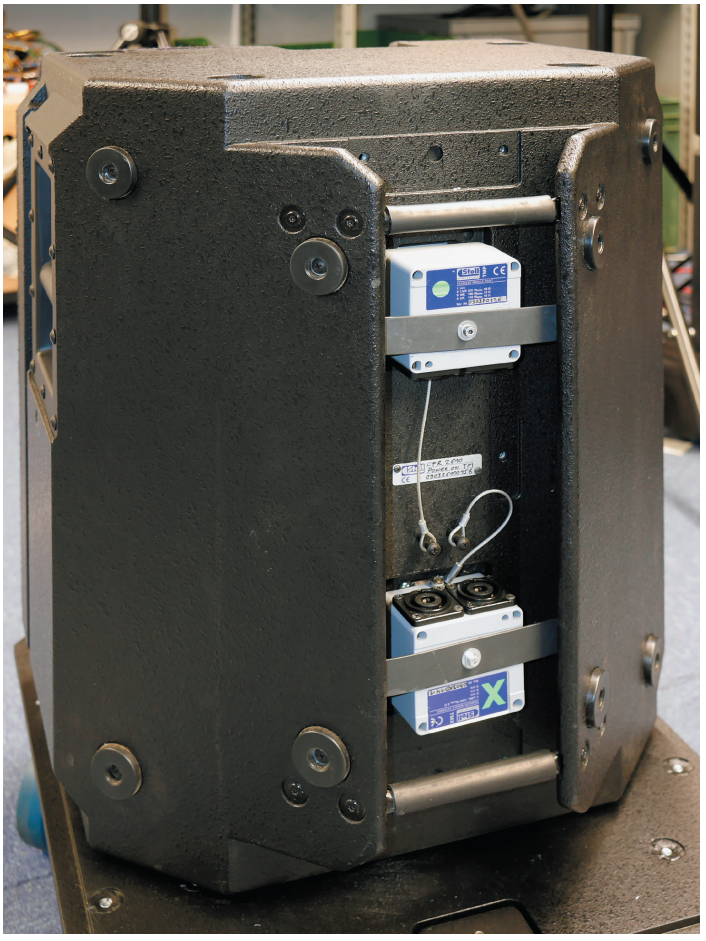
As with a display, in which different activations of the optical pixels yield different overall visual pictures, the Acoustic Pixel Technology in a similar way yields different overall "acoustic pictures" by means of different acoustic activations of the individual loudspeakers (the acoustic pixels).
The shorter wavelengths of the high-frequency range are then emitted by two medium/high-frequency systems specialised in the respective mode.

## Point source mode

A horn/driver combination consisting of a compression driver and a rotationally symmetrical horn is incorporated in the center of the baffle of the CFR2610, as a kind of center loudspeaker in the middle column. This is the high-frequency system for the point source mode.

In this mode, the six 5" chassis that immediately surround the high-frequency horn also reproduce the mid range up to the crossover frequency to the high-frequency horn system. The remaining four cone loudspeakers in the corners of the baffle only run up to approx. 400 to 600 Hz in the overlap with the inner ring and in this way act as a low-frequency extension. They effectively form a second "ring" around the central high-frequency horn.

The whole arrangement thus works more or less like a coaxial loudspeaker with a high-frequency horn in the center, only that in the construction at hand the cone loudspeaker for the low mid and mid-range has been split into six individual chassis, while the outer four only function below approx. 500 Hz. All ten 5"-chassis operate in the low frequency range in both point and line mode.



*Front and back of the Stoll CFR2610 Convertible. The transfer modules with Speakon connectors are easily discernible on the back.*

As far as low-frequency reproduction is concerned, the ten 5"-chassis have a total membrane surface that is even somewhat bigger than that of a single 15"-loudspeaker. So there is no need to doubt whether the CFR2610 is also full-range-capable as an individual system. Splitting the membrane surface into ten 5"-chassis, however, has the advantage here that first of all the drive is stronger due to a total of ten magnet systems and voice coils, and the effective voice coil surface for heat dissipation is larger than one of a single 15" chassis. In addition to this, one can operate a 5" chassis up to a higher crossover frequency at the upper end of it's frequency range. A 15" loudspeaker would have to make compromises in this respect.

A hypothetical, comparable 15" speaker would have to have a voice coil with a diameter of approximately 20cm diameter for the same electrical power handling capacity and a force factor (BL) of approx. 35 N/A (Newtons per Ampere)!

By the way, molded parts are built into the front grill which fit to the cone membrane shape of the 5" chassis and free two sound exit openings per chassis. This way they act as a kind of phase plug for a controlled sound radiation in the midrange. The advantage of this design is, firstly, that the transmission range of the 5"-chassis is extended to somewhat higher frequencies and the level of efficiency in the top octave is improved by approx. 5.5dB. At the same time, the number of sound exit openings is doubled, which effectively means that from an acoustic standpoint more or less twice as many correspondingly smaller speakers are active. This is also an advantage for operation in the line array mode. More about this later.

## Line array mode

While in the point source mode the 5"-chassis are activated in such a way that they effectively work in a concentric ring around the high-frequency horn.

For operation as a line array speaker one needs – easy to guess – a linear array of loudspeakers. The 5"-speakers must therefore be driven in a different way for this.

Let us remember: In the CFR2610, the 5"-chassis are arranged in three columns. The right-hand-side column, consisting of four chassis – seen from in front of the loudspeaker system – is driven as a group for the line-array mode in such a way that it reproduces the mid-range up to the crossover frequency of approx. 2,400Hz to the high-frequency path.

Due to the sound transmission mechanism mentioned before, the effect occurs

that acoustically, this four-chassis-line-array appears as a set of eight correspondingly smaller sound radiators which are located close together.
This brings advantages when it comes to meeting the criteria formulated by Christian Heil for a line array that functions as a line source [2]. These require, among other things, that the individual speakers of which the line array speaker consists are arranged in the useful frequency range with a spacing of less than half a wavelength.

In the example of the CFR2610, using the wave-guide solution described above, in effect eight speakers are distributed on a length that corresponds to the box height. They are therefore, in effect, arranged with a spacing of 580mm/8 = 72.5mm. The line-array criteria for the source spacing would thus be fulfilled up to a frequency of 2,365Hz, which means that the crossover frequency to the Mundorf AMT at approx. 2,400 Hz is logical and rational.

The left and middle columns, seen from the front, with a total of six 5" chassis, only work in the low midrange up to approx. 400 to 600 Hz in an overlap, which is to say together with the chassis of the right column. This way the horizontal radiation angle is retained at approx. 100° down to a frequency that is determined by the total width of the 5"-chassis configuration. Sophisticated FIR filters make it possible for the radiation characteristics to remain symmetrical despite the non-symmetrical operation of the 5"-chassis assembly.
Because of the longer wavelengths in this frequency range, there are no problems with the spacing of the single sources or due to the fact that the 5" chassis are arranged next to each other in two columns.

The high-frequency path is particularly interesting, of course, as this is always the real test in line-array development – because the requirements are especially difficult to fulfil here owing to the relatively short wavelengths in the high-frequency range.
If, for example, one wanted to adhere to the spacing criterion up to an upper frequency limit of 16kHz, then the individual sound sources would only be allowed to have a diameter of little more than 10mm and would have to be arranged tightly together. With direct radiators, such as dome tweeters, this would perhaps not be impossible, but would be at least very complicated technically.
Many line-array systems here take the route of using a compression driver. For this purpose, a waveguide must then be developed that converts the round sound exit opening of the driver into a rectangular sound exit opening in such a way that an even wave-front ideally occurs at this rectangular opening.

This is much easier said than done, and there is already a great variety of designs and even patents for this purpose. This is not least of all due to the fact that well-functioning designs are often already patented, and as a developer one has to come up with something new if one does not want to pay any licence fees, or the patent holder simply does not want to grant any licences for the desired design.

In many cases, the end of the story is a more or less complicated waveguide, which of course can work well, but will also takes up further space in the enclosure in addition to the compression drivers themselves. Space is scarce in a speaker system like the CFR2610 Convertible, however, because the boxes are meant to remain compact while nevertheless housing two separate high-frequency systems, in order to allow for electrically switching between the two modes.

The solution for the line-array high-frequency path chosen by developer Dominik Stoll follows the concept of "simple is ingenious" by using a tweeter that already has a rectangular sound exit opening due to its operating principle and produces a good approximation of an even wave-front at this opening.

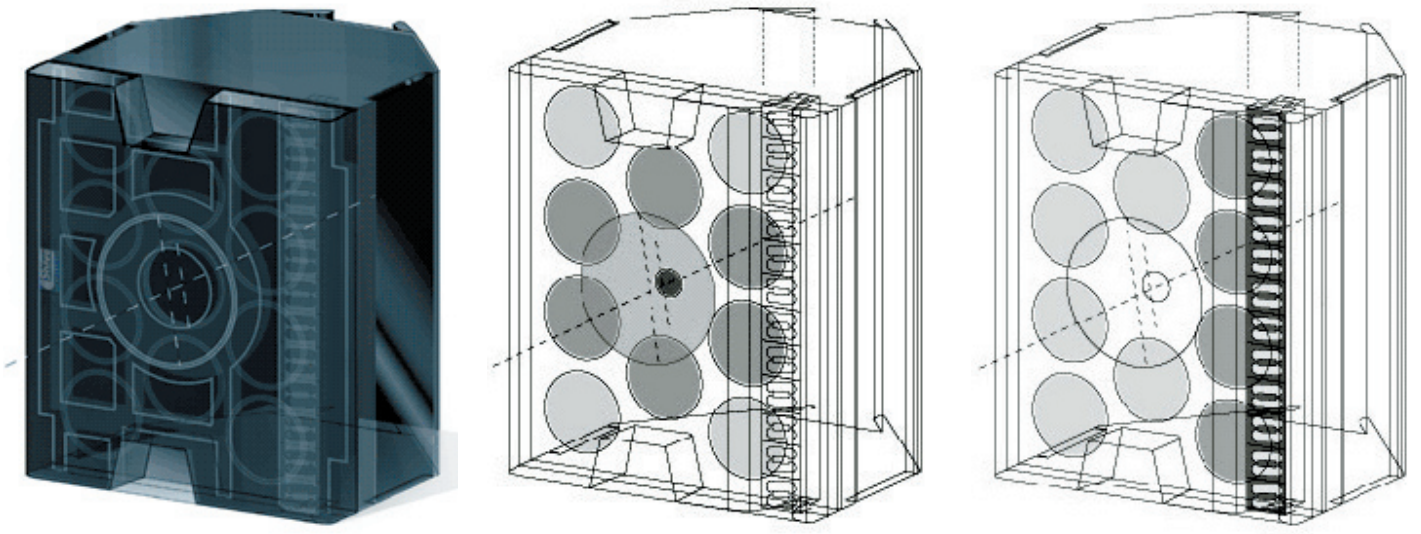
### Mundorf ProAMT

This tweeter is a special variant of the ProAMT (Air Motion Transformer), produced for Stoll Audio by the Cologne manufacturer Mundorf. During the past few years we have already often reported about the ProAMT in different versions and proven its fundamental suitability for use in a PA system, as also shown by our own measurements.

In fact the new AMT membrane production in Hürth near Cologne was only recently the subject of a report in Prosound (issue 1/2019). This makes it possible to realise even customer-specific designs within a manageable time-frame – a major advantage because membrane manufacturing is key for this transducer technology.

In this case, Dominik Stoll had given very precise specifications as far as the length, design and other dimensions of the ProAMT for the CFR2610 Convertible were concerned.

The result was a tweeter with rectangular sound exit opening that is almost exactly as long as the box is high, within the framework of the design constraints – which is to say it fulfils the requirements for a line array in an almost ideal way. On top of that, thanks to the Air Motion Transformer principle, the level of efficiency is higher than with a classic magnetostat.
In this case, however, Dominik Stoll was not trying to get the highest possible level of efficiency at any price. Rather, the Custom AMT high-frequency system was intended to get as close as possible to the desired dispersion behaviour and sound characteristics. If the price for this is lower efficiency this can easily be compensated for with an increased use of amplifier power, because with such a long membrane as in the ProAMT for the CFR2610 Convertible, the membrane surface is large enough to dissipate the heat arising even at higher loads.



*Graphic representation of the layout and different modes of the Stoll CFR2610 Convertible (see text)*

In the design of the loudspeaker one can therefore shift the optimisation between efficiency and sound quality in the direction of sound quality and in exchange reckon with a greater requirement for amplifier power. A similar approach has also been taken with the sub-basses. More about this later.

Speaking of power handling capacity: The AMT technology in the STOLL CFR2610 Convertible in the Kofmehl has actually already been in constant use for ten (!) years for all sorts of events such as concerts, discos etc. and has not been spared when it comes to volume either (within the permitted limit values). The house system was not bought by Kulturfabrik Kofmehl back then, but instead rented from the supporting PA company which is accordingly also responsible for technical maintenance. Its loudspeaker expert Stephan Isenring had asked Mundorf whether it would be advisable to have a non-routine change of the membrane after such a long operating time. However, this was not necessary, in line with corresponding experience gathered by Mundorf, which has supplied virtually no replacement membranes to its customers since 2007.

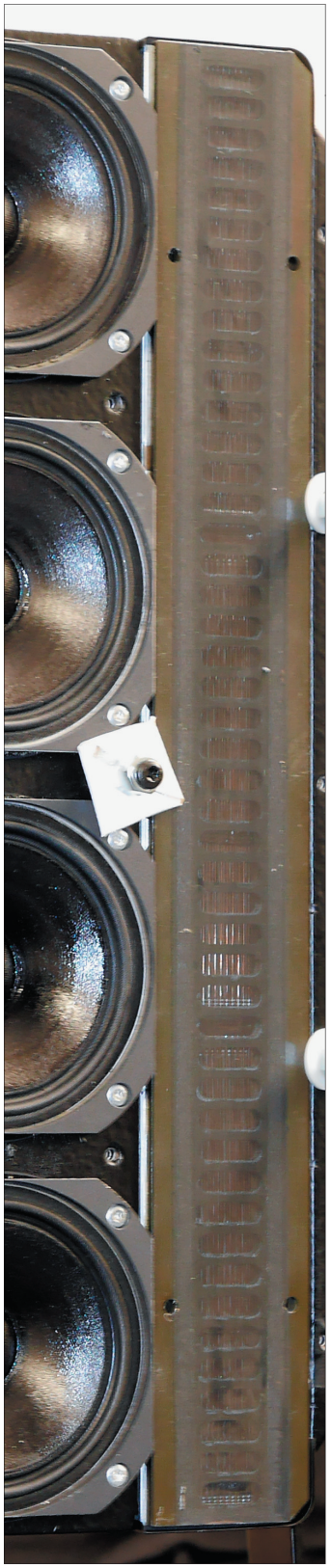
An important advantage of the ProAMT in the development of a line-array is that it supplies the desired rectangular sound exit with equiphase sound emission over the entire sound exit opening surface by nature, without the need to develop complicated waveguides for that purpose or to take patents into account. In this case, the speaker designer's work consisted more of specifying appropriate mechanical, electrical and acoustic key data to the component manufacturer in such a way that the resulting Custom-ProAMT would be ideally suited to use with the CFR2610 Convertible.

Incidentally, in a conversation about the system, Dominik Stoll pointed out that there is a further requirement especially for the high-frequency system of a line-array, which is often not acknowledged at all or regarded as not so important: The vertical radiation characteristics of a line speaker as the ideal model for a line-array PA arises from the superposition of the sound radiation from all sound sources in the entire array. This means, including the high-frequency range, that sound radiated from all array elements must reach every listening area in the audience to create the desired radiation characteristics. For this purpose, each surface element of the sound exits in the whole array must have very wide emission characteristics – ideally up to 180°. With many line-array designs working with high-frequency horn systems this is not necessarily the case. Especially with very curved arrays, it can thus occur in the high-frequency range that not all array elements are still radiating sound to each point in the audience. In favourable circumstances this can mean that not the whole array length is effective, in unfavourable circumstances the vertical emission characteristics can break up or exhibit undesirable side lobes.

As far as this aspect is concerned, the ProAMT is unproblematic because its membrane basically emits the sound without a waveguide or horn that would somehow limit the dispersal angle, unless the speaker developer were to deliberately incorporate this into the box's acoustic design.

With the CFR2610 Convertible there is actually only a waveguide for controlling radiation horizontally, in the form of a short horn attachment which is presumably meant to increase the acoustic effective width of the line source to approx. 9cm in the lower part of the ProAMT's operating range. This corresponds to the width of the sound exit openings of the 5" midrange speakers.

The wave-guide for the ProAMT thus ensures that the nominal dispersion angle of 100° horizontally is also adhered to at the lower end of the tweeter's transmission range and in addition



*Mundorf Custom-ProAMT with removed wave-guide in a Convertible experimentation system in the laboratory of Stoll-Audio*

corresponds to the dispersion angle of the mid system in the crossover frequency. With higher frequencies, this sound transmission then acts as a short horn with a nominal dispersion angle of 100°.

### Sub-bass

To support and extend the low-frequency range in the Kulturfabrik Kofmehl, a total of four Stoll IL3500 Infralow sub-basses are used, which are placed below the stage. The name Infralow does not just sound good, it also refers to the special concept of the Stoll sub-basses.
Unlike the majority of the sub-bass designs on the professional PA market, the Stoll sub-basses are not based on bass reflex designs, but instead work with closed boxes. According to developer Dominik Stoll, this has very positive effects upon the sound quality, especially in the bottom octaves, in that the system can transmit down to 8Hz with electronic drive control. The normal, factory-setting filter setup is set to 18 Hz -6dB with only a second-order high-pass characteristic, which is to say 12 dB/octave. It can be reset by the user, although a lower cutoff frequency of course also means lower maximum SPL. In practice, the factory settings have done well. Because many rooms and halls have marked normal modes in the range of below 40Hz, however, this room gain can be used and the system calibrated on site so that the desired ultra-low and "jet-black" low end fits harmoniously into the overall picture.

Classic bass reflex sub-basses of course use the advantage of an improved level of efficiency and higher power rating in the low-frequency range offered by a bass-reflex enclosure. On the debit side, however, is the fact that a bass-reflex sub-bass is at least a fourth-order high pass. Normally, however, a tuning of even 6th or 8th order is used, because an additional electronic high-pass filter limits the lower frequency limit to prevent damage to the speaker chassis due to excessive membrane displacements.
In bass-reflex speakers, the additional resonator dampens the membrane displacement in the range of its tuning frequency and thus ensures greater power handling capacity, among other things. The membrane displacement is only limited, however, in the frequency range of resonance and above the tuning frequency. Below the resonant frequency, the speaker membrane is virtually no longer dampened at all, so the membrane displacement increases greatly in this range and can damage the speaker.

A loudspeaker in a closed box behaves differently. Below the resonance frequency of the speaker when installed, the membrane motion is compliance controlled (i.e. dominated by the influence of the membrane suspension). This means that the membrane displacement is proportional to the applied electrical signal. For very low frequencies, the membrane displacement therefore does not become bigger and bigger, but instead basically follows the electrical signal. One therefore does not need a special protective filter to limit it, and instead the system works in effect without any kind of electrical additional high-pass filter. Modern amps go down very low, typically having a lower frequency limit of below 5Hz. If that means too much low end, due to room acoustics or because you want to achieve more dynamic range, STOLL recommends the use of a low-shelf filter, which produces a gentle roll-off. This will impair the phase and thus the group delay and ultimately the impulse response much less than an electrical high-pass filter, which are today typically used in front of bass reflex systems as 4th order filters. In any case, due to this concept, a STOLL Infralow System offers entirely new possibilities for shaping the deep bass range and below. In cinemas, they have been used to realise applications that allow a frequency response down to 5Hz, reproducing impressive earthquake-like effects, more felt than heard, which are after all to be found in modern film productions. It is not for nothing that the *.1 channel of a cinema sound system - the LFE, i.e. "Low Frequency Effect" channel - is explicitly defined without a lower limit (quasi down to 0 Hz).

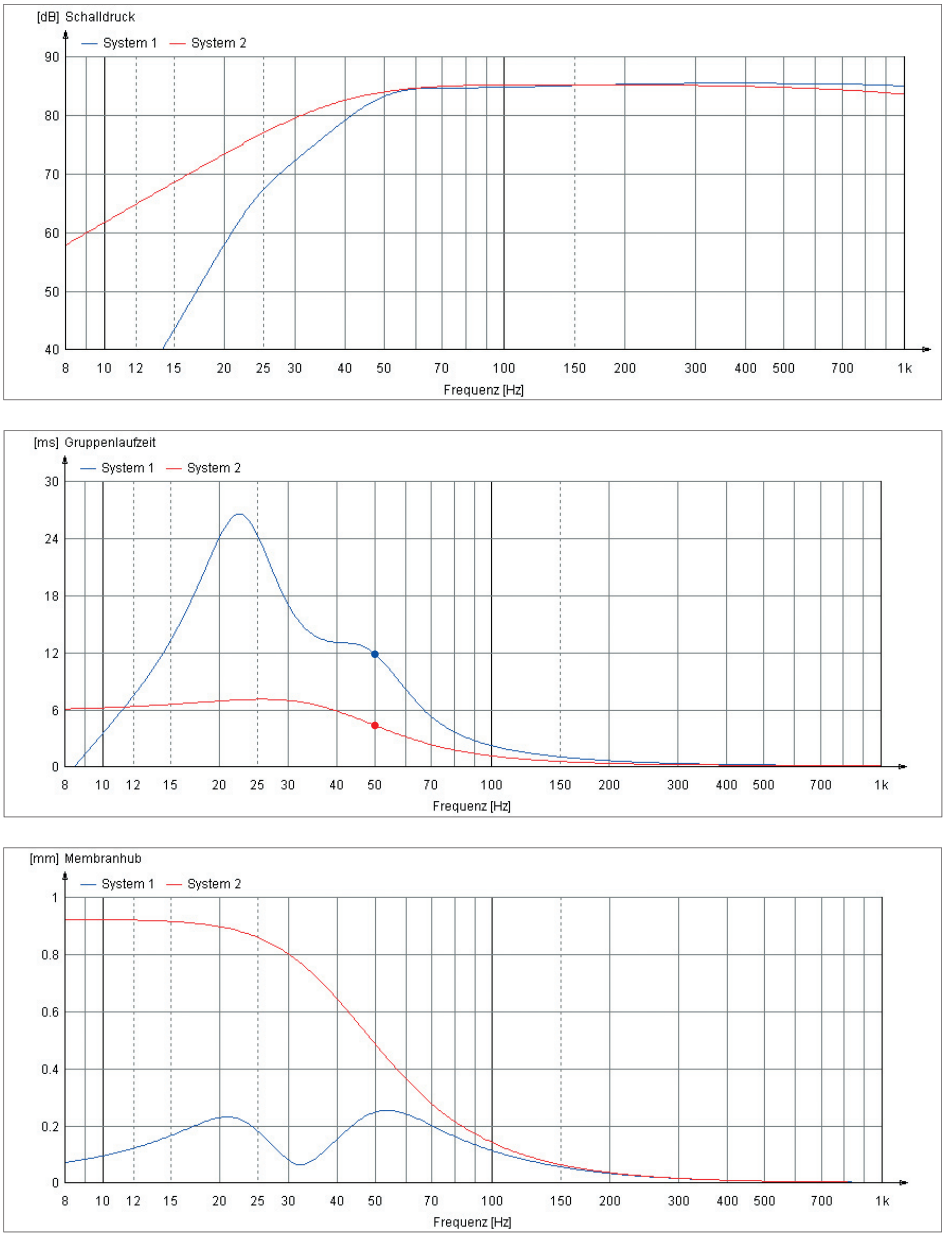
In contrast to this, on typical bass-reflex subwoofers, both the tuning frequency of the bass-reflex resonator and the protective filter are still in the range of frequencies used for music and can therefore also have an effect on the sound.

In order to illustrate the fundamental line of

thought of this approach, we have carried out a computer simulation of the low-frequency response of a bass-reflex system and also of a loudspeaker with closed housing.

**Important: These simulations have virtually nothing to do with the STOLL sub-basses in terms of housing size, chassis selection and tuning, they are only intended to clarify the basic concept.**

The three graphics show the amplitude frequency response, the frequency response of the group delay and that of the membrane displacement for the two systems. System 1 (blue) is the bass-reflex box, system 2 (red) the closed system.
For the simulation we have tried to adapt the amplitude responses in the design frequency range (from circa 45Hz upward) to each other as well as possible. In order to achieve this, similar chassis from the same manufacturer have been used, the Thiele-Small parameters of which are better suited to closed or bass-reflex housings respectively.
The bass-reflex system has in addition been given a high-pass filter to protect against excessive membrane displacement. This was tuned so that the membrane displacement below the design frequency range is not larger than within.
In the comparison of the two systems, it can be seen that below the lower frequency limit, the amplitude response of the bass-reflex system decreases substantially more sharply than the closed one. The kink in the falling flank comes from the additional protective filter, which one would presumably not leave as it is but instead tune somewhat differently if one were designing a real sub-bass.
An important difference shows up in the frequency response of the group delays: bass-reflex resonators and protective filters unavoidably also produce group delay distortions. For example, in our simulation, the reflex variant had a 2.7 times higher group delay at 50Hz than the closed box. It is highly likely that this can be heard, in the form of imprecise bass reproduction, for example.




*Computer simulation of the frequency response of sound pressure level, group delay and membrane displacement for two example bass loudspeakers with closed (red) and bass reflex housing (blue) with protective filter against excessive membrane displacement.*
***Important: This computer simulation has nothing to do with the technical data and loudspeaker components of the Stoll IL3500 Infralow sub-bass! It is only intended to illustrate the fundamental concept.***

Dominik Stoll also confirmed this for the comparison of his Infralow sub-basses to classic designs, but commented that one can hear the differences best in an open-air situation, because there the sonic differences between the two sub-woofer concepts cannot be obscured by any influence from room modes and other room acoustic effects in the low-frequency range.

In the frequency response of the membrane displacement, our simulation also showed the price that is paid for sonic advantages: for the same sound pressure level, the membrane displacement in the closed box is greater than in the bass-reflex box, partly because in the latter,

*Developer and managing director Dominik Stoll in a laboratory room of Stoll Audio. On the outside, the photo shows two Convertible experimentation systems, the tall loudspeaker system further inside is the big STOLL CUSTOM Master Grand studio monitor, which we heard for comparison purposes during our on-site visit. Under the label STOLL CUSTOM, Stoll Audio develops and produces loudspeaker systems for a wide variety of fields of use, specially tailored to the respective application.*

the bass reflex port takes over a large proportion of the sound emission in the region of its resonant frequency, and the loudspeaker membrane therefore does not have to move so much. The closed design also has a poorer level of efficiency. This cannot be seen in our graphics, however, because the inputs for both systems have been set so that their amplitude frequency responses are as equal as possible in the used frequency range.

The larger membrane displacement, says Dominik Stoll, is the price – or luxury – for more correct reproduction in the bass range. His design solution for this requirement is an enormous air displacement volume per front surface. The Stoll Infralow has an effective membrane surface of more than 82% of the gross front dimensions. The four (!) 18“ drivers used for each sub have an extremely long stroke (xmax linear of +/- 19mm!) and are driven by powerful amps (typically 6 to 12kW for four 18 inchers).

## Amping

On the subject of amps: The system in the Kofmehl is driven by four 4-channel amplifiers Lab.Gruppen PLM12K44, two of each per side, with each amplifier driving three parallel Stoll Convertible CFR2610 and a Stoll IL3500 Infralow. This way all four units can be looped through for each amp using 8-pole Speakon. In the Kofmehl, thanks to the duplicated 4-pole Speakon output on the amp, the speakers are double-wired with a Y-adapter cable and thus effectively driven with 8mm² cross-section per conductor for maximum damping factor and reliability.

Crossover functions and the complete system equalisation including FIR filtering suited to the loudspeakers are performed by the DSPs of the Lab.Gruppen PLM12K44 amplifiers. Stoll Audio sells these amplifiers as system amplifiers for the Convertible CFR2610 system, but customers are not restricted to these. Anyone already using products of another amp manufacturer in-house can also use that manufacturer’s amplifiers, provided that a CDS-capable DSP controller is used.

## So how does it sound?

Of course, what is more interesting than all the technical descriptions and details of special solutions is how the whole thing ultimately sounds. This was precisely the reason to set off to Solothurn and get a listening impression at a normal concert event with thoroughly challenging programme material.

On the day of our visit, Candy Dulfer was playing with her band. Her music can definitely be described as funk; a series of pieces called for assertiveness in the vocals and in different instruments as well as precision of bass reproduction.

From a sound-mixing perspective, the concert ranged from a homogeneous big-band sound, in which the different instruments were not meant to stand out independently, but rather to fit into an overall sound, to pieces with a strong focus on a fat, assertive sound from individual instruments or voices.

The Stoll Convertible PA-System mastered all of this with flying colours, without putting too much sonic emphasis on itself with a pronounced PA sound; this is presumably also a result of using ProAMT in the high-frequency path. Over the course of the concert I had the increasingly strong impression that the Stoll Convertible System is basically a platform that simply carries language and music – equally well for different tonal emphasis – into the audience.

In fact the STOLL Convertible system also achieves an outstanding, very even distribution of level and frequency in the concert hall, just from the line-array of six elements. The whole hall, from the front edge of the stage across the whole parquet to the two differently high tiers, is well covered with the approx. 3.6m-long line-array, without fills or delay speakers. Only a small VIP balcony under the ceiling right at the back is still covered with an additional speaker that freshens up the medium-high-frequency range from approx. 500Hz.
We heard a funk concert that evening, but I had the impression that the whole thing would have worked just as well for an open-air classical event, for example.

I must add here that this is not some personal figment of my imagination, but that I was also able to hear this at least to some extent. On the afternoon before the concert, in the development laboratory of Stoll Audio, we had the opportunity

to hear a somewhat different kind of Convertible system also with a range of pieces of music that we regularly use in our loudspeaker tests. While not wanting to anticipate the results of such a test, what I heard before and at the Candy Dulfer concert was very convincing.

I think that we are looking here at a PA system that bears international comparison and moreover offers the advantage of being able to use each loudspeaker element either as a point sound source or a line-array element.

Of course, there is also the matter of the price. The amount of technical effort that Stoll Audio puts into their systems is not exactly small - so a system like this cannot come cheap. As a point of reference, Dominik Stoll said to me on-site that as a rule of thumb, per meter of array length, the Convertible System is a similar price to internationally common systems.
The commercial net price of a system like the one installed in the Kulturfabrik Kofmehl, with twelve Stoll CFR2610 Convertibles and four Stoll IL3500 Infralows, including rigging, is below 80,000 euros net.

Literature:

[1] Chr. Heil, M. Urban, „Sound Fields radiated by Arrayed Multiple Sound Sources“, AES 92th Convention, Vienna, 1992

[2] M. Urban, Chr. Heil, P. Bauman, „Wavefront Sculpture Technology“, AES lllth Convention, New York, 2001

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