QSC

CINEMA AUDIO SOLUTIONS

Whitepaper: Why QSC doesn't recommend Line Arrays in cinemas

Sound system design is always guided by three basic factors: the program material, the space in which it is to operate, and budget. Any experienced sound system designer will tell you that the process is most definitely not a "one size fits all" exercise, and in fact, even with the most current technology, there are always tradeoffs.

That's the bad news. The good news is that with a solid understanding of real-world audio applications, a system can be designed that performs well for nearly any application that balances the tradeoffs to the satisfaction of most concerned parties.

Compared to other areas of professional sound, cinema sound presents a fairly controlled set of circumstances. We know that the program material will be provided by a pre-recorded soundtrack that has been carefully mixed by professionals in a controlled environment. We know that the listening spaces (i.e., cinemas) virtually anywhere in the world will share some common characteristics. And we know that the economic model of the cinema exhibition industry creates strong budgetary constraints when it comes to the purchase and installation of cinema sound systems.

Most manufacturers of cinema sound equipment also offer systems for professional "live" sound, but the two applications couldn't be more different. The program material, acoustical space, and budget realities vary considerably.

Cinema Sound	Live Sound
Dialog intelligibility is top priority	High SPL is top priority
No open microphone or feedback concerns	Multiple open mics require careful attention to avoid feedback
Create the same auditory experience (i.e., frequency response) throughout the room	Create even SPL coverage
Screen loudspeakers must go behind screen, where space is limited	Loudspeakers can be suspended from above over stage; space is not usually an issue
Screen loudspeakers must preserve Left, Center, and Right localization as created on the dubbing/mixing stage	Localization is not a factor; an artificial stereo image is about as complex as it gets
Musical content plays secondary role to telling the story through images and dialog	(For music performances) Music fidelity is top priority; images (when used) support the musical experience
Environmental ambience is re-created by surround channels and loudspeaker arrays through the room	Environmental ambience is provided by room acoustics
Rooms are typically longer than they are wide with fairly standard length-to-width ratios, and balconies are rare in modern cinemas	Rooms are typically wide (often fan-shaped), balconies are common

Fig. 1. A comparison of the different requirements of cinema sound and live sound applications.

Line Arrays in Sound Reinforcement Applications

In professional sound reinforcement, line arrays have become the preferred method of providing audio coverage for sound reinforcement in large spaces. With good reason, too, since line arrays produce a coverage pattern that is well-controlled in the vertical plane, and fairly wide in the horizontal plane—a good match for most performance spaces. Of course, loudspeakers based on the line source concept have been around for decades, beginning with the early "P.A." columns of the 50s and 60s. They have evolved to a point where line arrays are capable of providing excellent coverage for sound reinforcement applications in many venues. However, the typical cinema is not one of these venues[1]. There are many reasons why this is so. Here are eleven of them:

1. Cinema soundtracks are mixed on multi-way loudspeaker systems.

A key objective in cinema sound is to re-create the sound as it was heard on the dubbing/mixing stage during the post-production process. Most of these spaces are smaller than a typical cinema, and have well-behaved acoustics. A line array system in this type of room offers no advantage and would make little sense. Instead, well-designed 2-, 3- or 4-way systems where one loudspeaker is used for each band (e.g., low frequencies, mid-frequencies, and high frequencies) are the norm (Fig. 2) for each Left, Center, and Right screen channel location. For the best "translation" to the cinema, soundtracks should be played back on sound systems of a similar design methodology.

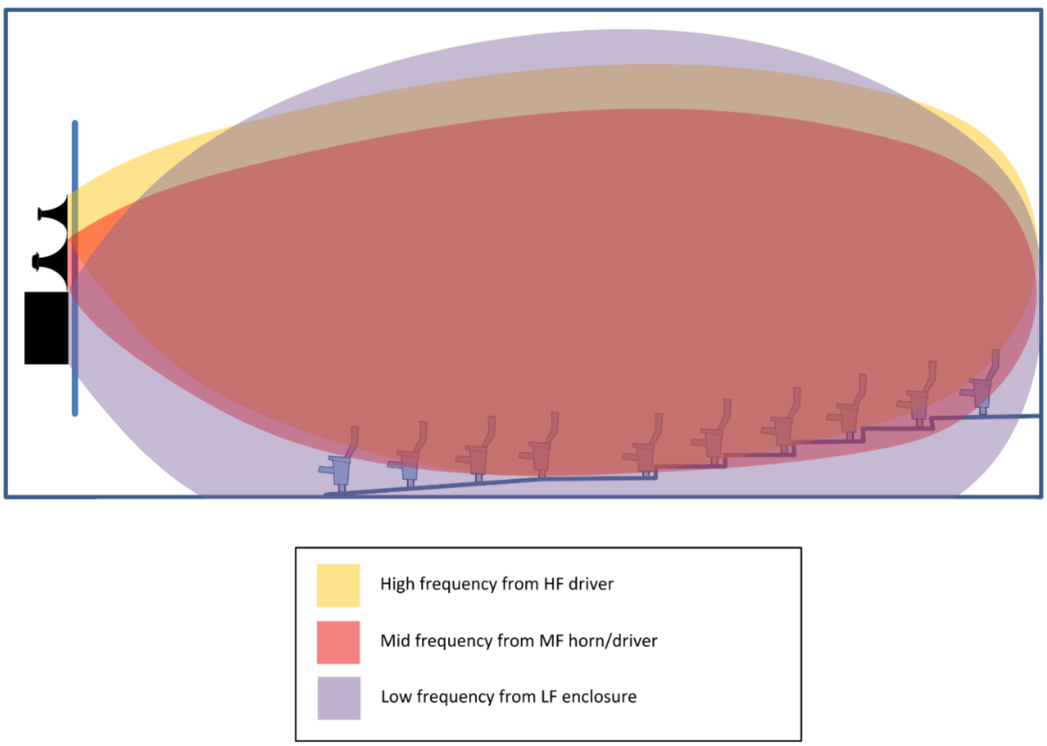

Fig. 2. Conventional multi-way screen channel loudspeakers project low, mid, and high frequencies evenly from a single source location.

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[1] QSC has significant experience using line arrays for cinema content in non-standard rooms. As the audio supplier for ShoWest and CinemaCon conventions, QSC has used our WideLine™ line array loudspeakers with great success in the 4,000-seat Colosseum at Caesars Palace and the Theatre of the Arts at the Paris Hotel. Line arrays are a great choice for these rooms due to their unusually large size, wide fan-shaped seating, and (especially in the case of the Colosseum) wide vertical coverage angle required for the balconies. A conventional point source solution would produce neither the coverage nor sound levels required for these rooms.

2. Line arrays require skilled expertise in order to design the appropriate system for a given space, and to implement them in the field.
The number, size, and type of line array elements, the degree of "splay" angles between them in a vertical hang, and any required DSP applied to each array is highly dependent on the specific characteristics of the room. Determining these factors requires considerable experience and the use of specialized software design tools, which would require an entirely new set of technical skills on the part of the cinema sound system provider. Another installation issue is that line arrays must be suspended from above. Since even small line array elements can weigh at least 40 lb (18 kg) each, the total weight of a typical multiple box hang with steel rigging hardware can easily exceed a ton or greater—times three for Left, Center, and Right if used in a cinema. Besides requiring special expertise in rigging, this also places greater demands on the building structure itself.

3. Line arrays require more space behind the screen.
In order for a line array to achieve the desired narrow vertical coverage (a key reason for using line arrays) down to a reasonably low frequency, they must be fairly long. For example, many experts believe that a minimum length for a line array is at least 3 to 4 meters. Also, most line arrays are articulated (curved), and depending on the shape of the curve, it can add significant depth to the assembled array, requiring more space behind the screen (Fig. 3).

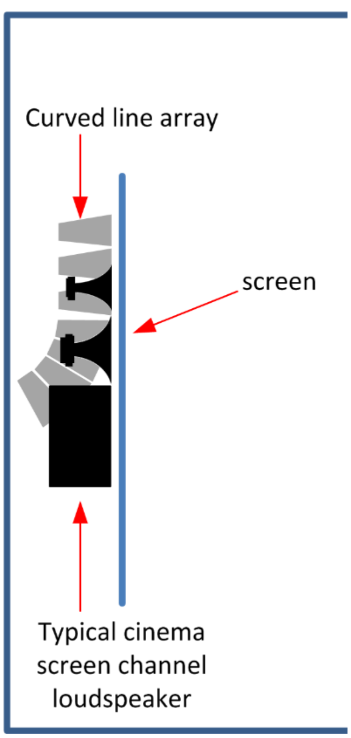
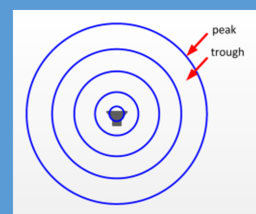


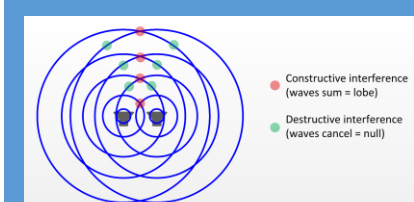
Fig. 3. A curved line array requires more space behind the screen compared to a typical multi-way screen channel loudspeaker.

WHAT IS INTERFERENCE?

Wave interference is the interaction of two waves moving in the same medium. There are two types: constructive and destructive. As sound waves travel through air, air molecules are compressed and rarefied (de-compressed).



When the compressions meet at the peak of the wave cycle, constructive interference occurs, and a lobe is formed producing higher sound pressure level in that region. Likewise, when two troughs meet, it also creates constructive interference. When a peak from one sound source meets the trough of a wave cycle from another sound source, destructive interference occurs, and a null is formed.



Multiple lobes and nulls are created at different physical locations relative to the sound sources, and are both frequency and level dependent.

4. Line arrays do a good job of producing even SPL coverage in a large space, but at the expense of consistent frequency response.

Because of the multiple interactions between the drivers and the multiple arrivals of wavefronts from front to back, the frequency response of line arrays can be inconsistent, or even ragged in a poorly implemented system. For live sound, where the performance may have no specific reference which it is attempting to re-create, consistent SPL throughout the listening area may be a priority over smooth frequency response. In cinema applications, however, consistent frequency response is more important than consistent SPL, since we are trying to re-create a common "sonic palette" for a large audience in order to convey the creative intent of the filmmakers. Consistent loudness throughout the room is less important than consistent sound quality from seat to seat. In fact, some patrons (especially the elderly) may even choose their seating location distance based on a listening level preference, or "loudness".

5. Curved line array elements cannot easily be implemented in a solid baffle wall.

A solid baffle wall with adequate acoustical treatment remains one of the best ways of minimizing behind screen sonic reflections, reducing box edge diffraction, and providing loading at low and low-mid frequencies. For any cinema application, the construction of a full or partial baffle wall is a highly recommended practice[2]. The curved nature of most line arrays (Fig. 4) makes it difficult (if not impossible) to construct a cost-effective baffle wall that can accommodate a loudspeaker shape where each element projects sound from a different plane.

Fig. 4. Line arrays are often comprised of multiple identical components and are often curved in order to achieve the desired vertical coverage pattern.

6. Line arrays typically produce a significant rear lobe.

All conventional line arrays attempting to approximate the theoretical "line source" will produce a strong spurious lobe toward the rear (and often top and bottom) of the array. This can be controlled with carefully applied signal processing, but even these measures can create new unwanted lobes which affect sound quality and coverage. A rear lobe may be less of a problem in a live performance venue compared to a cinema, since stage depth is greater and there are no listeners in close proximity. But in a cinema with (typically) solid walls within inches of the behind screen loudspeakers, the lobe will almost certainly be reflected back into the listening area, causing unwanted interference. A full, solid baffle wall could minimize this problem, but (as discussed in #5) any curve to the array would make it nearly impossible to construct.

7. Curved line arrays create multiple comb filters as a result of behind-screen reflections.

Loudspeakers positioned behind a perforated screen should always be placed as close to the screen as possible. But because the rear of the screen is acoustically reflective, sound will reflect from the screen backwards. Acoustical treatment on a full baffle wall will absorb much of this energy. Energy which is not absorbed will eventually return through the screen into the listening area at a later time of arrival, causing an audible "comb filtering" effect. The time arrival depends on the distance of the loudspeaker to the screen; the greater the distance, the lower in frequency the comb filter effect.

[2] Baffle "wings" which attach to the sides of loudspeaker enclosures are another method of achieving many of these same sonic benefits.

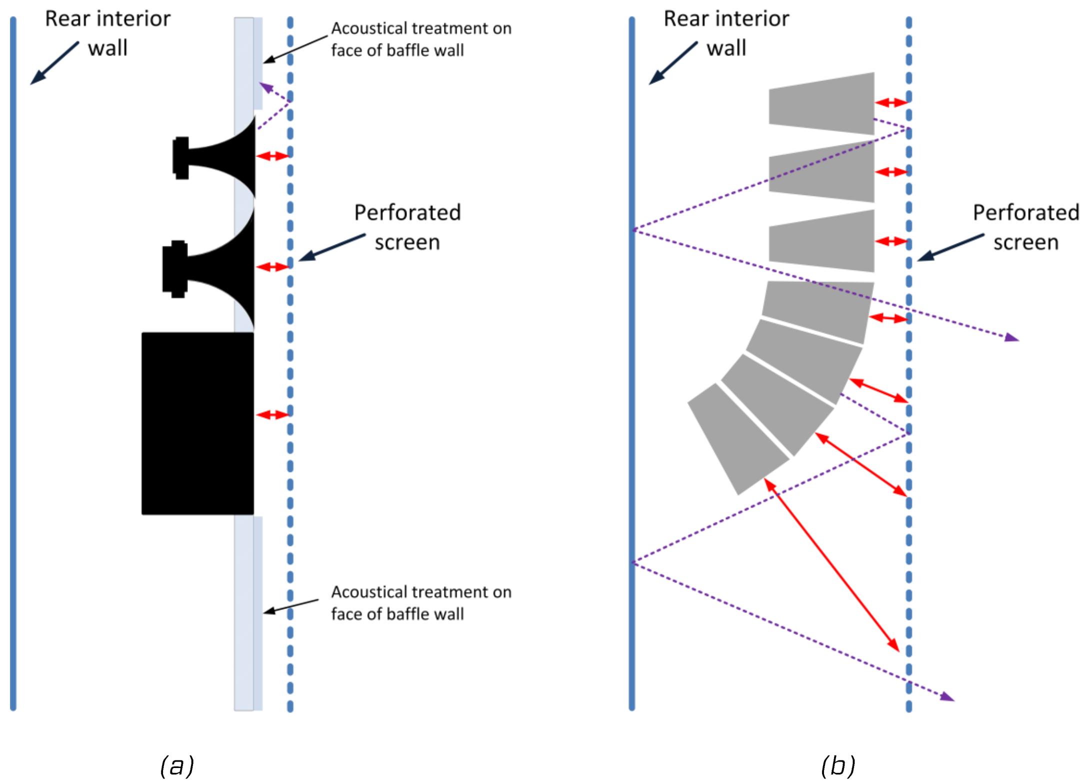


Fig. 5. A multi-way screen channel loudspeaker mounted in a full baffle wall (a) with acoustic absorption minimizes behind screen reflection and potentially destructive interference and comb filtering. A curved line array (b), with no baffle wall and increasing distances from the rear of the screen, creates multiple reflections of different path lengths and time arrivals.

A curved line array, where each loudspeaker element is producing the same audio signal at increasingly greater distances from the screen, creates a series of comb filters at multiple frequencies, which can produce audible smearing, a lack of sonic clarity, and inconsistent frequency response from seat to seat.

8. Line arrays are significantly more expensive than traditional multi-way systems.

With conventional line array systems, each line array element is a complete wide-range loudspeaker, with separate components for LF and HF (plus MF, in the case of a three-way system). Since they are built to professional sound standards intended for suspension from above and often for temporary use in a venue, they are built to a very high level of structural integrity, with internal and external steel hardware. Even fixed-coverage, single-box systems require many transducers, and it is necessary to use much less expensive and less capable components compared to a few top quality transducers. All of these design elements add up to significant cost, which is typically a major consideration in cinema sound system selection.

9. By design, the coverage pattern "edges" of line array elements do not cut off sharply. There is always some degree of pattern overlap between elements, which enables their directivity characteristics, but also causes potentially problematic lobes and nulls.

While the dispersion pattern from each line array element is narrow in the vertical axis, like any loudspeaker there is sound energy that is projected outside the rated coverage angles. For any given listening location, on- and off-axis energy from each element—which are producing the same signal—will reach the listener at different times, due to the geometrically different path lengths from each element (see Fig. 6). At some frequencies, this will result a random blend of phase summations and cancellations, which produce what audio professionals call "time smear". The perceptual experience of this time smear is a lack of clarity in the high frequencies, which can make music sound unnatural and dialog sound unintelligible.

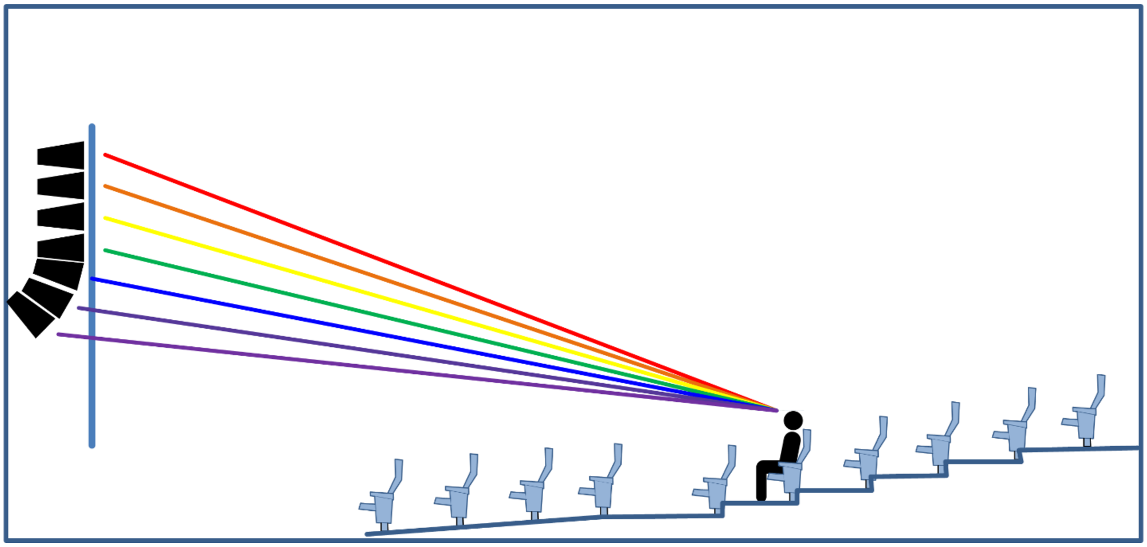


Fig. 6. The distance to a listener from each line array element is different, which can result in "blurred sound", or smearing.

The interaction of sound between two sources producing the same signal can also cause a series of lobes (areas of higher SPL at specific frequencies) and nulls (cancellation of specific frequencies, resulting in lower SPL at those frequencies in certain areas) (Fig. 7).

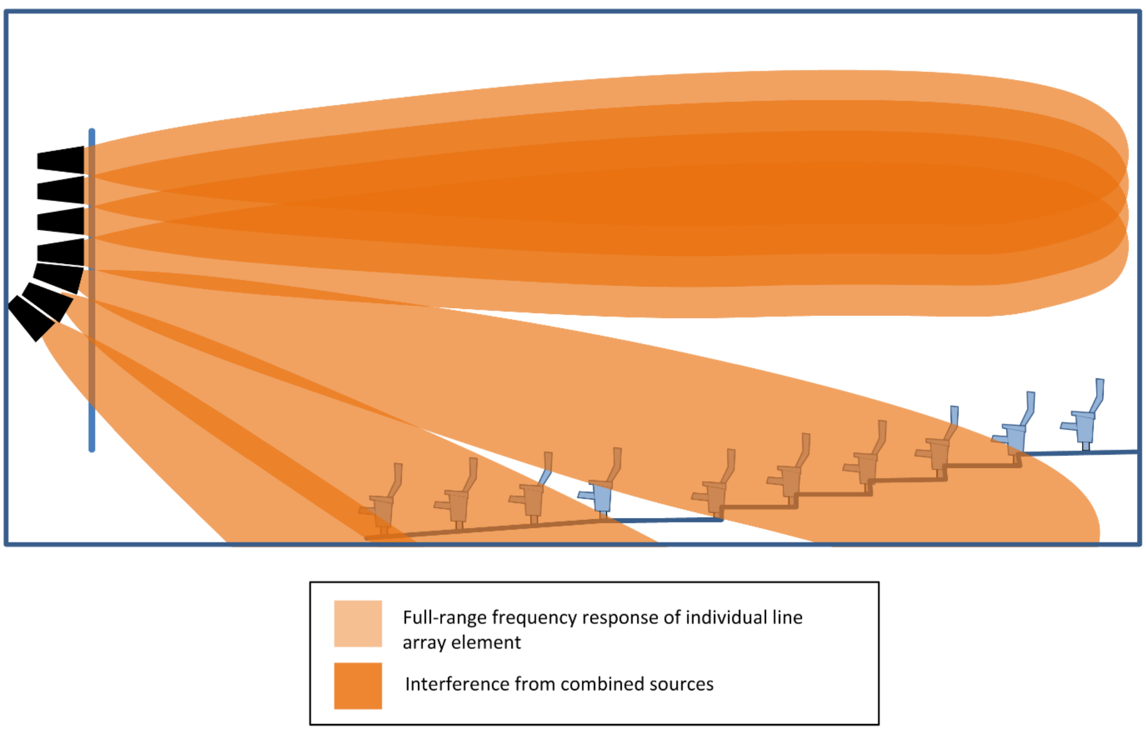
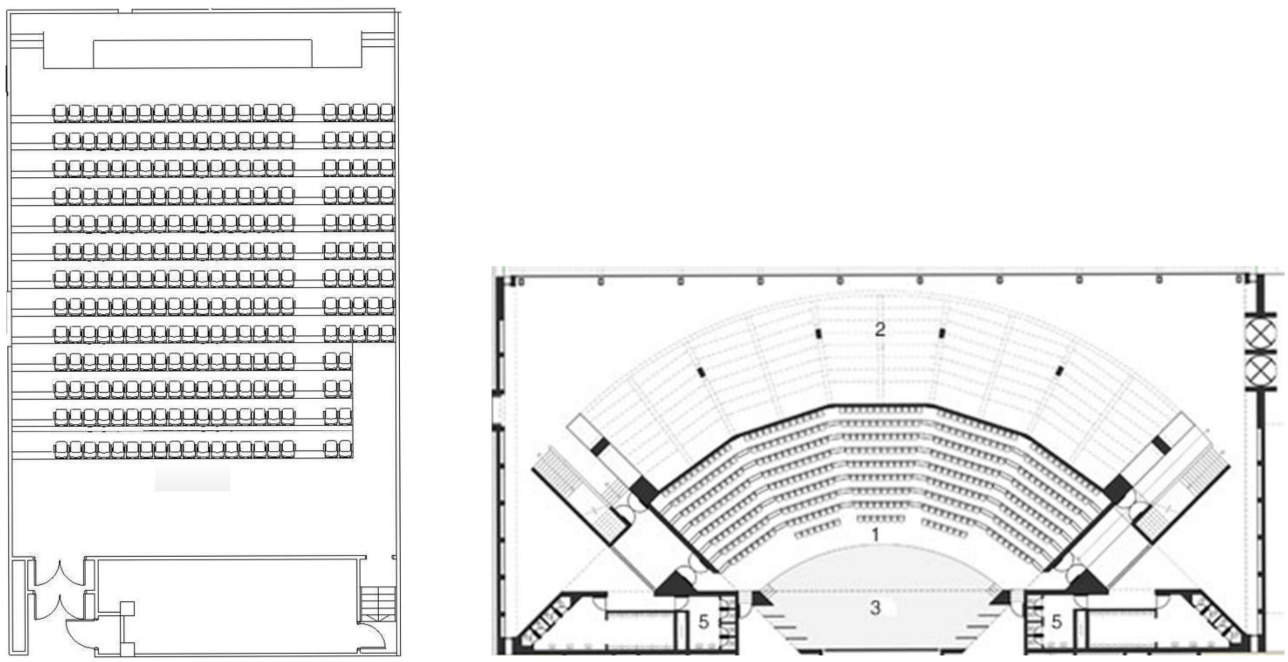


Fig. 7. A line array system projects the same signal source from multiple elements, which can result in nulls and significant pattern overlap and combing, due to interference at various wavelengths.

10. The typical cinema is not optimally shaped to take advantage of the benefits of line array systems. Modern cinemas are built to a fairly standard size and shape. Although there are many shapes and sizes, the average cinema is under 300 seats, about 60 to 70 feet from the screen to the last row of seating, and designed with an approximate 1.5:1 length to width ratio. Most cinemas have a fairly short reverberation time (RT60) compared to performing arts spaces. The optimal size and shape of a cinema is as much related to the economics of construction as it is to projection, sound, and sightline considerations. Most audio professionals would agree that line arrays are most appropriate for applications that require broad horizontal coverage, long "throw" distances, and narrow vertical dispersion (usually to address excessive reverberation). These requirements do not describe the average cinema. Line arrays are commonly used in performing arts centers, concert halls, and live theatre applications where the rooms are generally large, very wide, and may include one or more balconies (Fig. 8).



(a) *(b)*

Fig. 8. The average cinema is rectangular in shape (a), while many performing arts spaces are fan-shaped and may have multiple balconies (b).

11. Some of the claimed advantages of line arrays are based on a theoretical model which is impractical in the real world.

Many blanket-statement marketing claims about line arrays are based on an oversimplification of classical line source theory, which doesn't translate to the real world of line arrays in actual rooms. The concept of the "cylindrical wave front" and the 3 dB loss per doubling of distance (versus 6 dB loss as indicated by inverse square law) are two examples. Both may be somewhat true for certain specific frequencies at some distances, but they do not apply to across the entire frequency spectrum of a cinema soundtrack in an actual cinema.

Line arrays are a loudspeaker system design approach based on the theoretical concept of a line source. A line source as described by Harry F. Olson in 1957 is an infinitely long, straight line of omnidirectional acoustical radiating elements, all reproducing the same signal.

As described, a line source is theorized to produce a cylindrical-shaped wave, as opposed to the spherical wave produced by a point source. If the theoretical concept was practical to actually build in the real-world, it's easy to see how the benefits of such a horizontally-wide and vertically-narrow dispersion pattern could be useful in certain applications. However, practical considerations (like the condition of infinite length) obviously preclude building the true line source. The physical realities of attempting to build and use one compromises the theory, and thus it's impossible to claim a pure cylindrical wave front. Likewise, a 3 dB loss per doubling of distance really only applies broadly to the theoretical concept. While it's true that a very long line array could achieve 3 dB loss in the "near" field, the distance to which that near field extends depends on the length of the array and the frequency in question. No real-world line array could actually be long enough to achieve this across all frequencies at the distances required in a real-world venue. At a certain distance, which varies with wavelength (and thus frequency), line arrays will produce SPLs which drop off at closer to the 6 dB per doubling of distance typical of any radiating element.

Line arrays have proven their superiority for some applications, including large spaces with difficult acoustics. Many manufacturers of cinema loudspeakers (like QSC Audio Products) include line array systems in their product catalog for professional sound applications. But for the average multiplex cinema, they are neither necessary nor do they provide any real advantage over the use of a single transducer for each frequency band of a screen channel system.

CAN YOU REALLY "BREAK" THE INVERSE SQUARE LAW?

It's often stated that a line array can produce more consistent sound pressure levels from the front to the back of a room. But there is a point in the listening space where sound level decreases not at 3 dB per doubling of distance, but instead it will decrease roughly according to the more familiar "inverse square law" of 6 dB per doubling of distance. That distance is dependent on both the length of the line array, and the frequency in question, and can be calculated according to the following formula:

$$D = A^2/\lambda$$

Where:

D is the distance at which near field transitions to the far field
A is the largest dimension of the source
λ is the wavelength of the frequency in question

For example, if a line array is 2 meters in length, the near field extends only to 5.8 meters at 500 Hz, 11.6 meters at 1 kHz, and 23.3 meters at 2 kHz. A line array that's only 1 meter in length has a near field of less than 3 meters at 1 kHz. The shorter the array, the shorter the 3 dB near field is. For an average-sized cinema of 70 feet (21 meters), in order to include the entire audience in the "3 dB" near field at all frequencies (before crossing over into the subwoofer), you'd need an array nearly 8 meters long!