Loudspeaker Position Guide.

Recommended loudspeaker positions
for optimal immersive sound reproduction.

ALTITUDE 32

Industry reference immersive audio processor since 2014

About Trinnov

At Trinnov, sound is in our DNA with more than 20 years of research at the most advanced level. From our world-renowned room correction solution to our unique ways of optimizing your speakers, we have always been at the forefront of sound research to deliver the most advanced solutions to audio professionals. We are now as well a reference brand for integrators who want to push all immersive sound formats to their limits, bringing native decoding and the most innovative network remote support available on the market. Step into a world of acoustic fidelity and put yourself at the forefront of immersive audio using our unique hardware/software solutions.

Trinnov's diverse team of over 45 passionate people across 6 time zones worldwide shares a deep commitment to audio excellence, bringing hundreds of years of audio engineering and musical experience, extending across all departments of the company.

Now represented in 55 countries, with over 5000 high-performance installations worldwide, Trinnov is uniquely involved in all aspects of audio production. Trinnov processors are found in the world's most advanced professional music and film studios for production, mixing, and playback; in thousands of commercial cinema screens; and in the finest residential home theater and stereo systems.

By being present all along the audio chain industry, from content creation to delivering the most immersive sound experience in the home, we guarantee the integrity of the sound and deliver a unique sonic experience.

Recommended Loudspeaker Positions for Optimal Immersive Sound Reproduction

Sound Sense : Arcadian Odyssey
2019 CEDIA Global Awards Best cinema level III

INTRODUCTION

Trinnov introduced the Altitude[32] in 2014. Because of its unique hardware platform and software-based design, it not only supported Dolby Atmos® in early 2015 – two years before most companies could support Atmos – but we supported the rendering of up to 32 unique channels of information from the object-oriented format. To this day, only Trinnov can do so (and we have since gone even further).

With our unique ability to render object-oriented audio formats to more than merely 12- or 16-channels, we have had more experience than any other company in helping our distributors and dealers around the world implement truly high spatial resolution home cinemas.

Back in 2016, we decided we should update our early speaker placement recommendations "white paper" with everything we had learned implementing and helping to calibrate hundreds of such theaters. We thought it would take 5-6 weeks and result in perhaps 15-20 pages.

We were wrong.

Fourteen months later, we ended up with an 80+ page document designed to help our dealers take full advantage of the Altitude[32] unique capabilities. Its goal: to help our dealers design and implement home cinemas that were optimized for multi-listener cinemas and optimized for multi-format reproduction (Auro-3D®, Dolby Atmos®, DTS:X® and DTS:X Pro®).

Widescreen Review has generously offered to publish a series of articles that lay out the thinking behind these design strategies for the benefit of its readership.

HISTORY

Trinnov's Altitude[32] is a new generation of AV preamp designed to bring immersive sound to high performance home theaters as a complement to UHD video.

Trinnov was founded in 2003 to study and perform fundamental research into capturing, storing, and reproducing complex three-dimensional sound fields. In fact, the name Trinnov Audio derives from Tri (for 3) and Innovation – hence, Innovation in 3D Audio. As such, we at Trinnov have a great deal of accumulated experience and understanding of the complexity involved in creating convincing Immersive Audio experience and understanding that predates the current 3D sound formats.

Over the decades, cinema sound has evolved from mono to stereo, to matrixed four-channel sound (Dolby Pro Logic), and eventually to fully discrete 5.1 and 7.1 soundtracks. But, until recently, the audio was essentially confined to the plane of the audience. Immersive audio adds the essential third dimension of height to bring a degree of realism to the movie experience that had not been previously available.

But, while different formats (Auro, Dolby, DTS) fundamentally agreed on the optimal locations for either the 5 or 7 main channels for such soundtracks, there is no such consensus with respect to the optimal locations for the additional height channels. To the contrary, Dolby Atmos®, Auro-3D® and DTS:X® all have significantly different notions about where the "extra" speakers should be located. Reconciling these disparate recommendations is normally a matter of significant compromise. Ordinarily, you need to decide which layout recommendation you favor, resulting in the other two formats being reproduced with spatial errors due to the "misplaced" speakers.

What is needed is a sensible speaker layout that, combined with specific technologies, can play all three formats with as much spatial resolution and accuracy as the formats themselves support.

Fortunately, the trend in 3D audio is toward "object-oriented" audio. Once you go beyond the basic 7.1 (or potentially 9.1) listener-level speakers, each additional sound in a Dolby Atmos or DTS:X mix is encoded as a sound with spatial "metadata" associated with it. That is, each sound (music, special effects, Foley, etc.) also contains information about where the sound should be in space relative to the main listening position, and also how focused or diffused the sound should seem. Thus, overhead thunder might seem to come from everywhere, while a ricocheting bullet might be tiny while flying just over your head.

Moreover, all three of the Immersive Audio formats were designed with the presumption that their arrays of speakers are ideally placed relative to a single, main listening position (MLP). While this simplification might have been necessary when developing the technology, it causes potential problems when the listeners are spread over a larger area.

This white paper seeks to establish guidelines that resolve both of these problems: having a single, sensible array of speakers that works well for all formats, and for all listeners.

IDEAL ROOM PROPORTIONS FOR IMMERSIVE HOME THEATER

The optimal loudspeaker placement for the various immersive sound formats needs to meet many requirements, often contradictory. In addition, since the speakers are placed in a room, the room itself has a major impact on the speaker placement. Because of their specific dimensions and proportions, some rooms are more suitable for immersive sound than others. This section focuses on general guidelines with the goal to derive ideal room proportions to achieve the highest immersive sound performance for the three available formats within an immersive home theater. More specific speaker placement guidelines will be discussed in the following installments. As ideal room sizes may not be achievable, other sections of the document will discuss how to adapt the recommended speaker layout to the non-ideal room proportions (wide/narrow rooms, high/low ceiling rooms) in order to minimize its impact on the listening experience.

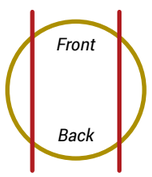
SPEAKER LAYOUT RECOMMENDATIONS FROM DOLBY ATMOS, AURO-3D AND DTS:X

As part of their respective formats, Auro, Dolby and DTS have developed their own and mutually incompatible speaker placement recommendations which consist of providing a recommended direction (both horizontal and vertical angles) for the position of each speaker relative to the main listening position (MLP). Such positions have been developed for a wide range of content (TV, pure music without picture, games, virtual reality) and a wide diversity of listening contexts (studios, high end home installations, mass market home installations, headphones, mobile).

As a result, these generic recommendations correspond to an idealized context with one listener surrounded by speakers, without specific constraints such as room size, screen, multiple listeners. Therefore, rather than interpreting such angles as absolute requirements for each individual speaker it is more important to understand the philosophy behind each format and how the layout is built. Even if various Auro, Dolby or DTS speaker layouts are able to reproduce perceived sound coming from any direction over a half dome above the listener (and therefore provide a true immersive experience), their philosophies are very different:

Dolby Atmos

Dolby Atmos uses a circle of speakers at ear level and 2 lines of top speakers.



TOP VIEW

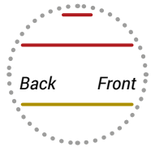
SIDE VIEW

Dolby Atmos can provide up to 34 loudspeaker feeds corresponding to predefined loudspeaker positions: 24 positions are distributed on the circle and 10 positions are distributed on the 2 ceiling lines. Any perceived direction is possible within a half dome above the listening plane but the Atmos speaker layout is specifically optimized to reproduce sound sources rotating 360° around the listener with a very high spatial resolution as well as for reproducing front-back overhead effects with a very high spatial resolution. Dolby recommends specific loudspeaker positions up to 15 speakers (9.1.6 configuration) and even 19 speakers in the near future (11.1.8).

Auro-3D

Auro-3D recommends stacking 2 layers of loudspeakers, one at ear level, the other elevated, along with the addition of a single top speaker.

TOP VIEW



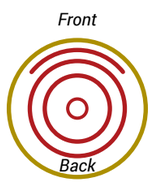
SIDE VIEW

This layout is optimized not only to reproduce 2 layers of sound but more importantly to reproduce sound sources between the 2 layers to achieve a continuous vertical spread of the sound image and an enveloping experience. Therefore, the elevation angle between the 2 layers is of special importance and should always be between 25° and 40°, with 30° as the optimal value.

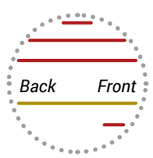
Auro-3D provides up to 13 discrete loudspeaker feeds corresponding to predefined loudspeaker layouts named 9.1, 10.1, 11.1 and 13.1.

DTS

In its full specification speaker layout, DTS recommends a more uniform sampling of a dome around the listeners composed of four layers of loudspeakers (one at ear level, two elevated and one below ear level) along with the addition of a single top speaker. This layout allows moving sound sources anywhere over the dome with a uniform resolution.



TOP VIEW



SIDE VIEW

The standard DTS:X renderer delivers up to 11 discrete loudspeaker feeds corresponding to a predefined loudspeaker layout named 7.1.4 and the new DTS:X Pro renderer provides up to 30 speaker locations.

Dolby Atmos, Auro-3D and DTS:X speaker layouts are, by definition, not compatible. Each requires a dedicated set of 3D speakers, which is highly impractical and a poor usage of available speakers. **The Trinnov Remapping technology combined with speaker placement recommendation from Trinnov is the only way to reproduce Atmos, Auro-3D, and DTS:X all on the same loudspeaker layout at the absolute maximum performance.** Trinnov recommendations about loudspeaker placement are further developed in these articles.

SOUND-TO-PICTURE COHERENCE REFERENCE VIEWING ANGLE

3D sound formats allow more accurate sound positions and subtle mixes in which the coherence between sound and picture is more critical than ever. To achieve sound-to-picture coherence, the L-R loudspeaker angle should match the visual angle of the screen. Practically, the L and R loudspeaker should be placed as close as practical to the edges of the screen (either behind the screen in the case of front projection or on the sides of the screen in the case of flat screen). Whenever possible, we recommend not exceeding the viewing angle of ±30.5° for UHD 4k video, which matches the usual 30° L-R loudspeaker angle expected for music and TV content. This was not the case for HDTV 1080p.

- HDTV 1080p: ±16.5° optimal horizontal view angle, 16/9 aspect ratio.
- UHD 4k: ±30.5° optimal horizontal view angle, 16/9 aspect ratio.

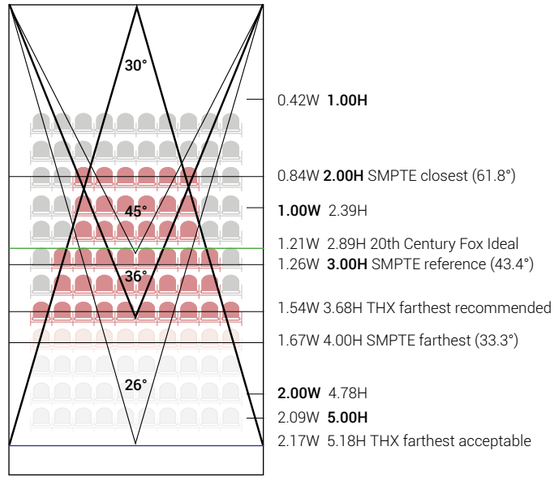
These recommended viewing angles are derived from visual acuity studies. In short, the increased resolution of UHD 4k allows you to "zoom in" on the screen (subtending a larger angle) without the picture becoming pixelated.

Visual angle is not only driven by pixel size but also by visual comfort. A high-performance home theater should reproduce the visual experience intended by the filmmaker. As a result, for film content, the view angle should comply with recommendations for commercial cinemas, dubbing stages and screening rooms:

- Reference horizontal view angle: ±22°
- Narrowest horizontal view angle: ±16.5°
- Maximum horizontal view angle: ±31°

Fortunately, the range of optimal visual angles for movies correlates well with the range of visual angles for video from HDTV to UHD 4k. This will no longer be the case with upcoming 8k video, which would (in theory) offer enough resolution to open the viewing angle to ±55°. But it seems preferable maintain a maximum view angle of ±31° because movies are designed and filmed for this size. Otherwise, the points of interest in the picture become too far apart and the audience has to constantly scan the picture to see everything, which creates discomfort.

However, if it is not possible to place the loudspeakers so as to match the view angle, the Trinnov Remapping technology will reposition the sound stage to the viewing angle and maintain the sound-to-picture coherence even if the loudspeakers are somewhat misplaced.



ACCOMMODATE THE ROOM SHAPE

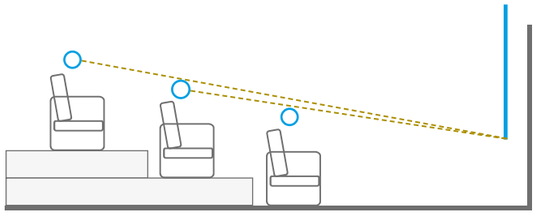
Of course, most of the time you will be working within an existing space, many of which will not be ideal in size and/or proportions.

- The minimum room width is imposed by the screen width with reference view angle of ±22° as seen from the main listening position (MLP).
- We recommend, if possible, placing the MLP at about ⅔ of the room length from the screen. Note that the seating position in the room should compromise neither the viewing angle nor sound-to-picture coherence.
- The room height is constrained by the ceiling and thickness of any acoustic treatment. Standard inner height for luxury private theaters is typically 2.8-3.5m.
- Some loudspeakers often must be moved away from their recommended position because of practical considerations (an entrance door, window or other architectural elements, etc.).

If the ideal speaker position recommendation is not possible because of the room shape, the Trinnov remapping technology will compensate for loudspeaker misplacements and retrieve the original 3D soundstage.

ENSURE SIGHT LINES

It is common to use screens wider than 4m, especially in high-end home theaters. On such screens, a full width 16:9 picture has 2.25m height and the bottom of the screen can be quite low with a normal ceiling height. The difficulty comes when the listening area has multiple rows and when the listeners sitting in the front can occlude the picture for the listeners sitting behind. This problem is usually solved by creating risers (raising each row of seats by approximately 30cm or 12 inches relative to the next row toward the screen). In extreme cases, very large screens may require stadium seating in order to avoid visual occlusion.



OPTIMAL SPEAKER ORIENTATION

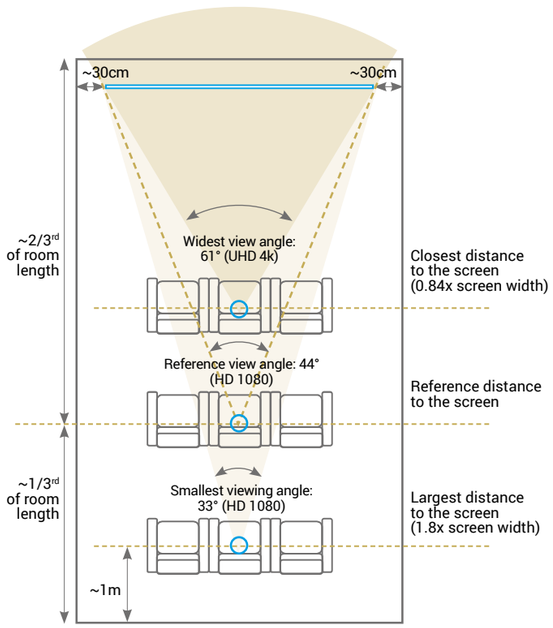
To achieve truly high-end cinema reproduction, the general recommendation is that whenever possible **all loudspeakers should point toward the main listening position**, just as is specified for professional cinemas and professional studios designed for immersive sound. Doing so will achieve a wide listening area, the most accurate source positions and the most uniform tonal balance as the sources are moving. In order to avoid sophisticated speaker mounting to achieve the exact pointing, it is a reasonable to use in-wall or in-ceiling speakers with pre-oriented/angled front plates, provided that the design of the loudspeaker allows it to be aimed at the reference position to within 20°. In this case, the Trinnov Optimizer technology will correct the frequency and phase response of the off-axis response of the loudspeakers and maintain the 3D sound imaging capabilities of the system.

With a less high-end approach it is also acceptable to **mount "shower"** (non-angled) loudspeakers to the ceiling and walls, but they should have wide dispersion. The Optimizer technology will recover the 3D soundscape from the listening position but the listening area with optimal 3D effect will be smaller unless the speakers have exceptionally wide and uniform dispersion. This "shower" approach can greatly facilitate the integration and often leads to a cleaner aesthetic.

Other methods are possible to achieve higher spatial performance over a wide listening area, such as to **pointing each speaker toward the opposite seat position** within the listening area, resulting in all speakers cross-firing over the listening area. Such advanced approaches will not be discussed here as the performance relies on both the directivity pattern of the speakers and the room acoustics.

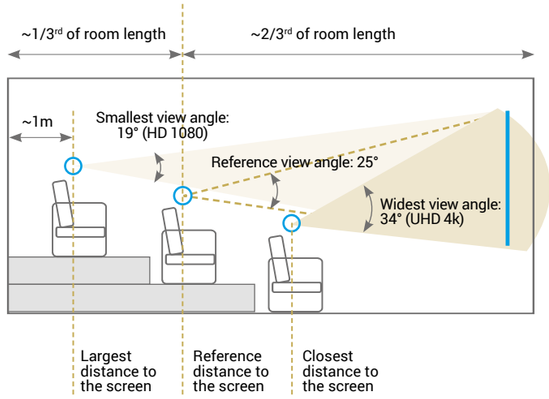
OPTIMAL ROOM PROPORTIONS

A home theater is primarily designed to reproduce film and the proportions of the room as well as the seating positions are optimized for picture. With modern projectors and UHD/4k video, the screen can achieve the reference view angle of ±22° found in a screening room or commercial cinema. The room must be larger than the screen width to avoid illuminating the sidewalls. On the other hand, the room should not be much wider than the screen width to ensure that the Dolby ceiling speakers are close to the walls and more compatible with the Auro-3D height speakers. Typically, an ideal room should be ≈30cm (1 foot) wider than the screen on each side. The room length should allow optimal distance to the screen with the main listening position (MLP) achieving a visual angle of ±22°. All other seats should provide an acceptable visual experience with a visual angle no wider than ±31°, which sets the distance of the front seat row to the screen at 0.84 times the width of the screen, and, with a visual angle no smaller than ±16.5°, which sets the distance of the rear seat row to the screen at 1.8 times the width of the screen. For both acoustic and speaker placement reasons (developed later in this series), it is advised that the back wall should be at least 1m behind the rear seat row.



TOP VIEW

If the home theater is an area in a multipurpose room, the ideal room proportions apply only to the home theater area, just as if there was a "virtual home theater room" within the multipurpose room.



SIDE VIEW

The recommended ceiling height is 3m, and a higher ceiling may be preferred as there will be smaller distance variations between the various ceiling speakers and the various seats providing a more uniform sound pressure field. In many cases, the effective ceiling height will be limited to less than 3m, not only because of the pre-existing physical room dimensions, but also possibly a lower ceiling to create room for in-ceiling speakers. Any ceiling height lower than 2.5m should be avoided whenever possible.

DIFFERENT SPEAKER GROUPS: SCREEN, SURROUNDS, WIDES, HEIGHTS AND SUBS.

The intent of a 3D immersive audio loudspeaker system is to produce a unique, three-dimensional soundfield in which the contributions of all the speakers combine to produce a unique 3D immersive experience. This being said, the primary goal of a home theater sound is to support a picture on the screen with listeners who are sitting at specific fixed positions with their heads orientated toward the center of the screen.

As a result, all possible directions from which sound can come are not equivalent. Different speaker groups need to be defined according to their functions and their positions need to be specifically optimized. The five groups are:

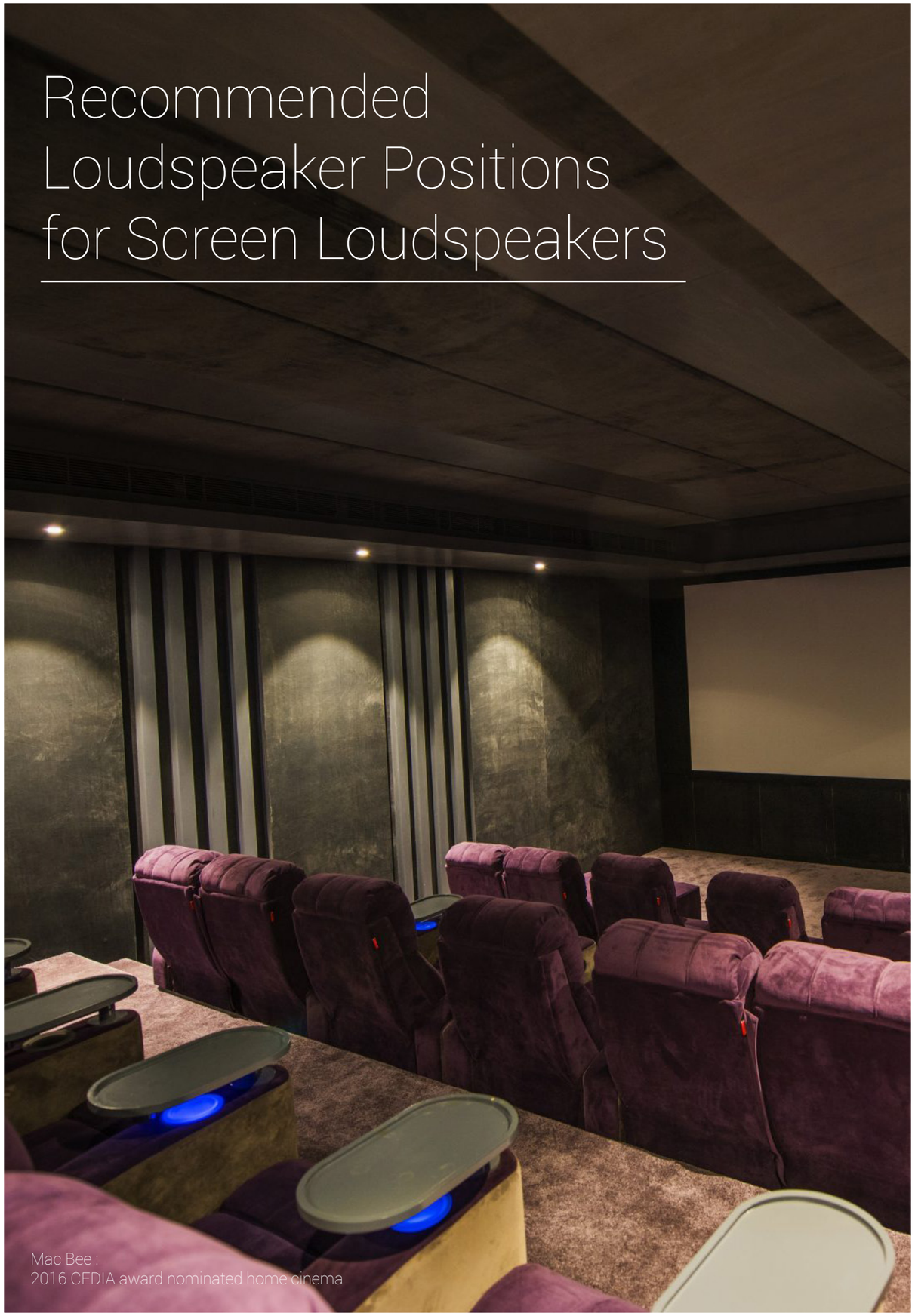
- Screen speakers
- Surround speakers
- Front wide speakers
- Height speakers
- Subwoofers

Logically, the recommended methodology for designing an immersive sound speaker layout is:

- **STEP1:** First, place **screen speakers** to match the **view angle** to preserve sound-to-picture coherence.
- **STEP2:** Then, define **surround speakers** (number and positions) based on the **listening area** and **room**.
- **STEP3:** Then, place the **front wide speakers** to **bridge screen and surrounds**.
- **STEP4:** Finally, define **upper speakers** (number and positions) based on **ceiling height** and **listening area**.

These STEPS will be developed in subsequent articles.

Recommended Loudspeaker Positions for Screen Loudspeakers



Mac Bee :
2016 CEDIA award nominated home cinema

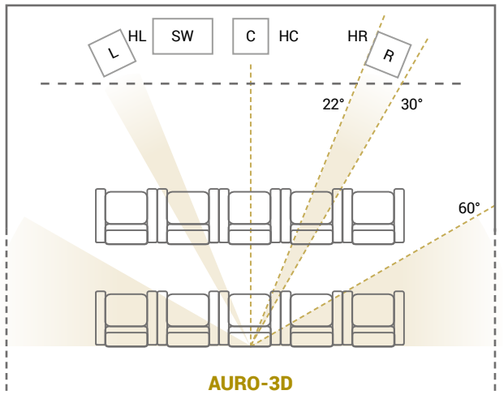
SCREEN LOUDSPEAKERS

In the last article, we summarized an approach toward designing the proportions of the room so as to best accommodate the somewhat disparate speaker placement recommendations of Auro-3D, Dolby Atmos, DTS:X and DTS:X Pro.

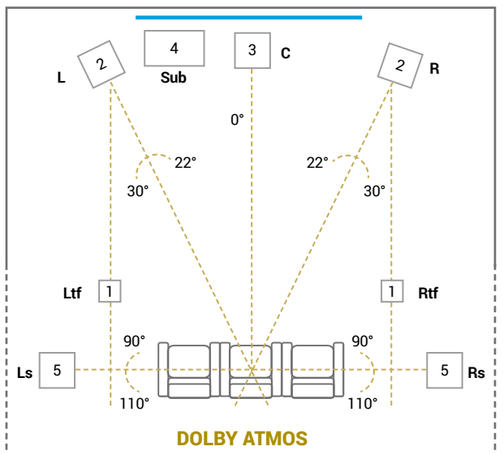
Fortunately, there is one area where all three formats can agree: the screen channels. However, that doesn't mean that there isn't some room for improvement over what is commonly done.

ANGLE RECOMMENDATIONS FROM DOLBY, AURO-3D, AND DTS:X.

The various immersive audio formats recommend a horizontal angle between ±22° to ±30° for screen speakers, which corresponds to recommended viewing angles for film and the recommended viewing angle for UHD 4k. These recommendations are derived from visual acuity studies.



AURO-3D



DOLBY ATMOS

Guideline 1: the included horizontal L-R angle should match the viewing angle.

The L-R angle should match the view angle formed by the screen so that the audio and video images match closely. If the home theater system is used mainly for films, the L and R speakers should be behind the (acoustically transparent) screen and as close as practical to the edges of the screen. In this case the L-R angle is slightly narrower than the viewing angle.

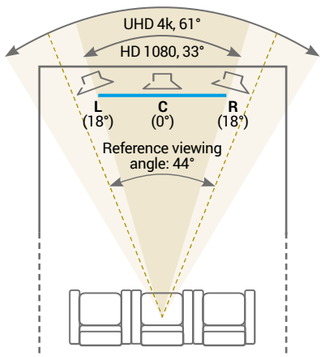
If the system is used for film but also music/TV programs, it is best to place the speakers next to the side of the screen to avoid the occlusion of the screen and improve the transparency of the sound. In this case, the horizontal audio angle is slightly wider that the viewing angle but at the same time closer to the ideal stereo angle of 30° which is preferred for this application. (Note that placing the L and R speakers close to the side walls makes the use of appropriate, passive acoustic treatment extremely important.)

In an acoustically-designed room, the placement of the L and R speakers can be slightly adjusted to improve the control of the first reflections against the side walls, in particular the angle of the ipsolateral reflection (the reflection coming from the sidewall nearest the speaker).

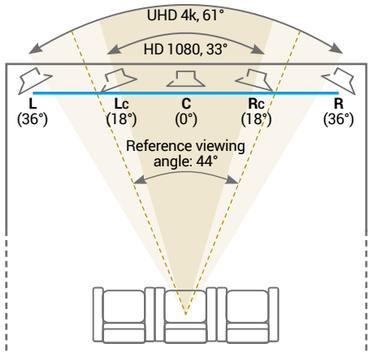
Guideline 2: Number of screen speakers: 3 or 5?

The number of screen speakers depends on the aperture of the visual angle from the reference position:

- If the visual angle is less or equal to ±20° (narrow screen), 3 speakers are enough, regardless of the other speakers.
- If the visual angle is greater or equal to ±35° (wide screen), 5 speakers are recommended, regardless of the other speakers. We recommend positioning the additional "inter" speakers (Lc/Rc) at the half angle between center and main L/R speakers. This uniform angular distribution of the speakers across the screen guaranties smooth, uniform angular panning of sound sources across the screen. Consequently, the inter speaker (Lc/Rc) will be slightly closer to the center speaker than to the main L/R speakers.
- If the visual angle is between ±20° and ±35° (most cases):
  - 3 screen speakers are recommended if the number of surround speakers is less than or equal than 8
  - 5 screen speakers are recommended if the number of surround speakers is greater than or equal than 10



TOP VIEW



TOP VIEW

the screen speakers may be too high and in most practical cases it is preferable to position the screen speakers slightly lower, but not lower than the bottom of the screen. This position improves subjective audible comfort and improves the differentiation of height effects, while maintaining good vertical coherence of the center channel with the picture.

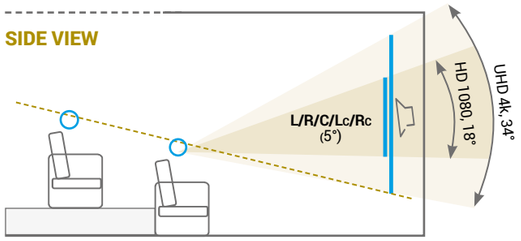
Guideline 4: Optimal speaker orientation

Several speaker orientation methods are possible depending on the project requirements and budget.

Flush or shower mounting is recommended in projects requiring simple speaker integration without complex mounting systems. In this case, however, the localization and immersive experience will be somewhat compromised for listeners sitting on the side of the main listening position.

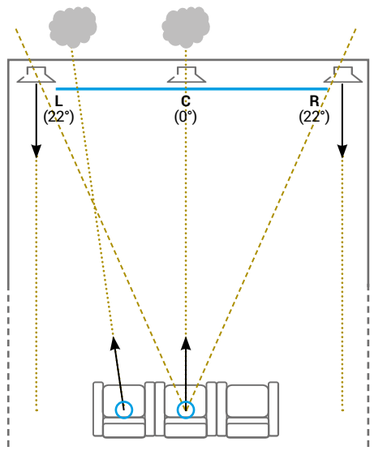
It is widely understood in the conventional stereo situation where L and R speakers reproduce an identical signal, they form a phantom sound source exactly half way between L and R as perceived at the Main Listening Position (MLP). Because of the directivity of the L and R speakers, however, a listener sitting to the left would perceive the L speaker as being louder than the R speaker, resulting in a shift of the image toward the left. (The earlier arrival time also tends to move the image to the Left via the Precedence Effect.)

This speaker orientation method is very sensitive to the room acoustics since much of the speaker energy is reflected off the adjacent wall, maximizing unwanted reflections and reverberation. Also, in the case of the Front speakers especially, it is also prone to maximizing unwanted flutter echo between the parallel front and back walls unless they are treated.



Guideline 3: Vertical alignment of the screen speakers

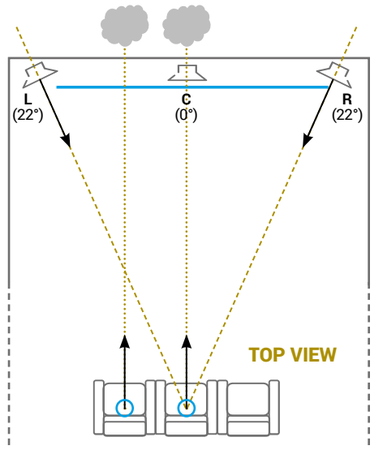
As the available resolution of the picture increases, the trend is to use larger and larger screens with a vertical viewing angle between 18° to 34°. In order to avoid visual occlusion between listener rows, it is advised to use risers for the rear seating rows and/or to elevate the screen. In order to maintain the sound-to-picture coherence, the screen channels should be vertically centered with the screen. However, if exactly vertically centered,



Flush/shower speaker orientation

TOP VIEW

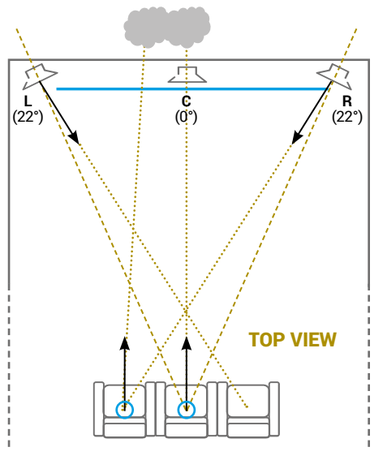
Pointing speakers toward the MLP is recommended if the integration allows for mounting system or if the speakers are pre-angled. This speaker orientation ensures best possible localization, immersion and tonal balance at the MLP while minimizing localization shifts for side seats. This speaker orientation method provides a result that is (slightly) less dependent on room acoustics as the energy projected out of the listening area is minimized.



Speaker pointing toward MLP

Cross-firing is recommended to achieve best overall localization and immersion for all seats at the expense of a slight compromise at the MLP.

To better understand the benefits of cross-firing, let's return to the stereo example in which the L and R speakers reproduce an identical signal forming a phantom sound source exactly half way between L and R when perceived from the MLP.

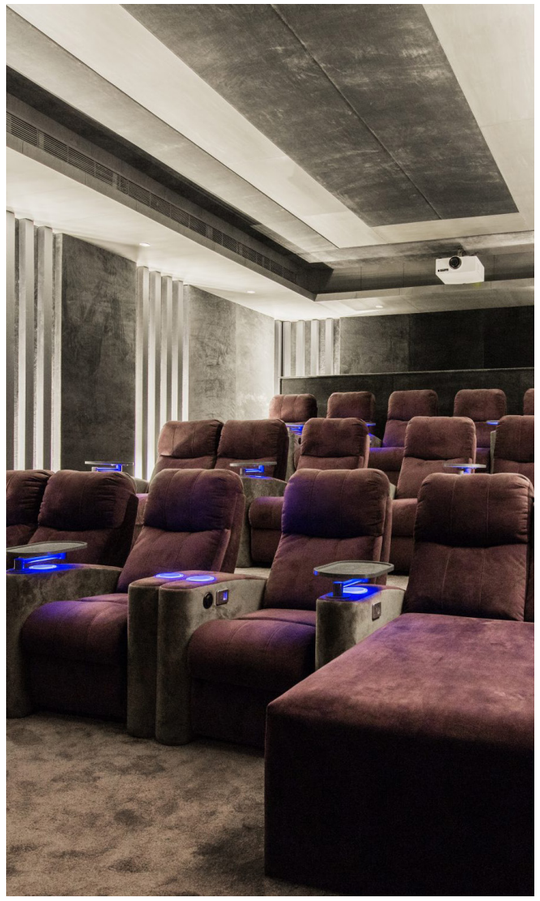


Cross-firing speaker orientation

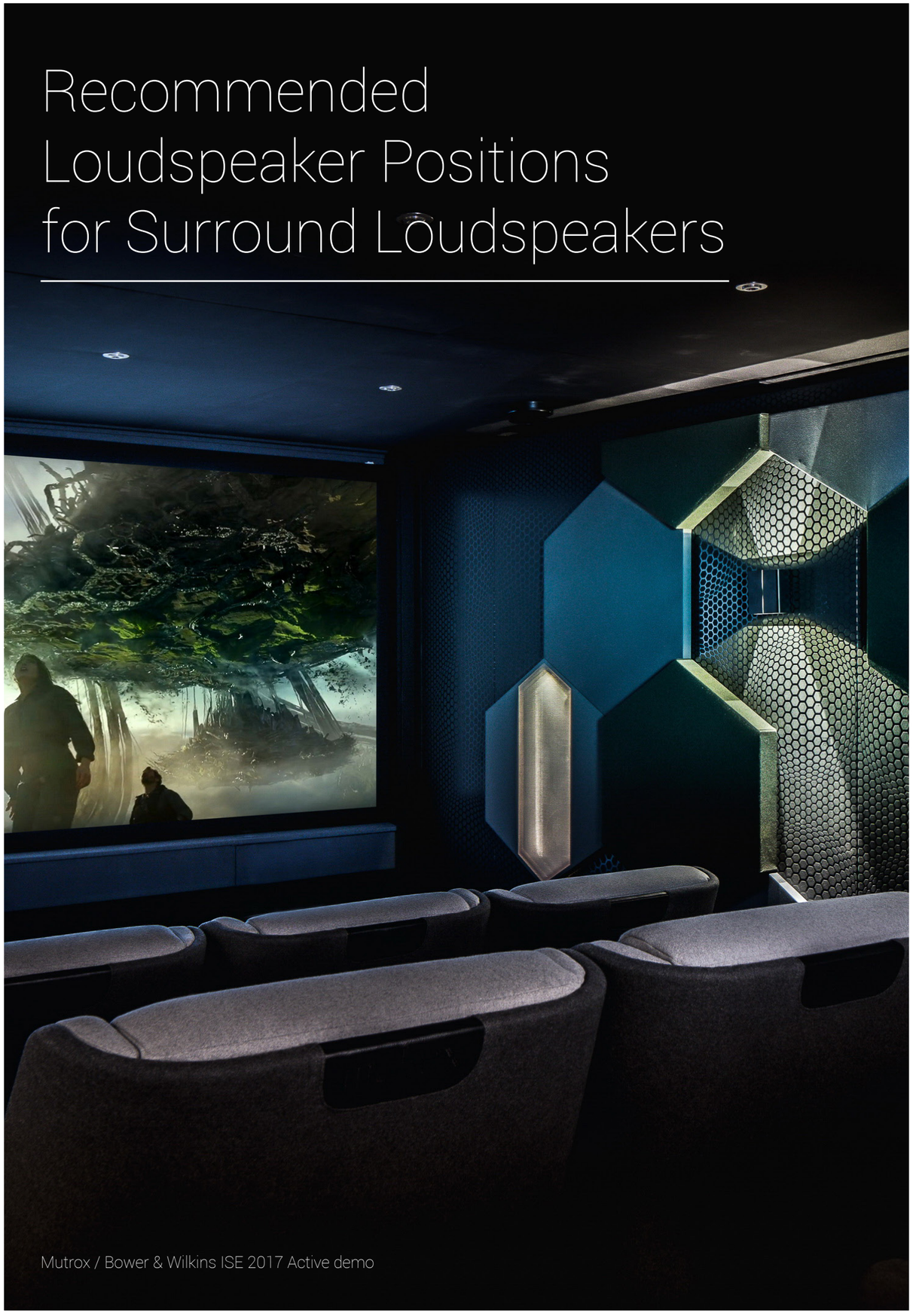
A listener sitting to the left would be closer to the L speaker (shifting the source toward the left) but at the same time this listener would be more on axis with the R speaker and more off axis with L speaker, resulting in a higher level from the R speaker. The result is that the phantom image shifts back toward its original position. The sound image is largely stabilized within the listening area. This cross-firing method requires selecting speakers with great off-axis response and great power response. The final result depends strongly on room acoustics design as the speakers project a lot of energy to the opposite walls.

This method should be used carefully and only in acoustically-controlled environments where the contra-lateral reflection (from the far side wall) receives broadband absorption. It must be avoided in any untreated, un-optimized room as the energy reflected from the opposite wall will decrease intelligibility as well as soundstage depth.

In the next article in this series, we will tackle the much more complex issue of determining how many surround speakers is optimal for various sizes of rooms and listening areas as well as their placement within those spaces.



Recommended Loudspeaker Positions for Surround Loudspeakers



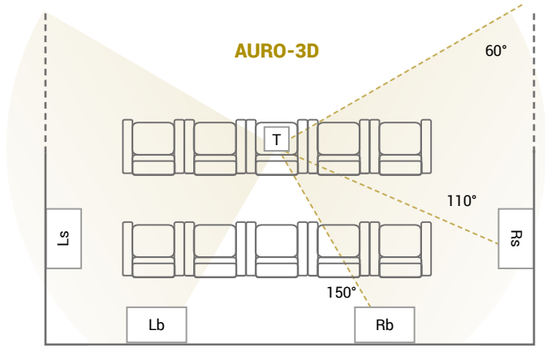
Mutrox / Bower & Wilkins ISE 2017 Active demo

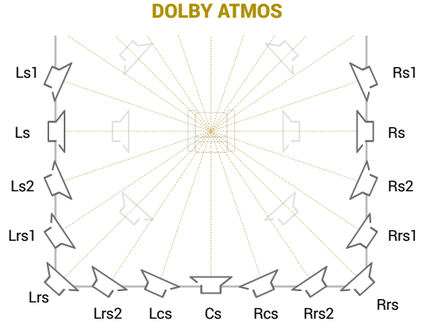
SURROUND LOUDSPEAKERS

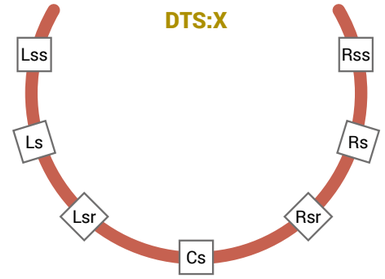
In the third of our series of articles on speaker placement recommendations for multi-listener, multi-format home theaters, we tackle what for many is the most challenging question of all: how do I decide what to do about my surround speakers? How many? Where? All three of the immersive audio formats were developed and defined under ideal, laboratory-based conditions wherein a single listener was surrounded by a specific array of loudspeakers. This constraint is practical and perhaps even necessary when developing an entirely new way of reproducing a complex, three-dimensional soundfield; however, it does not correspond to a typical home theater design, as will be seen.

RECOMMENDATIONS FOR A SINGLE LISTENING POSITION

The various immersive audio formats provide very similar recommendations for surround speaker layouts. All three formats recommend speakers to the sides and behind the central listener with even spacing.







These recommendations are directly applicable for the single-seat situation but need to be adapted to a multi-seat context.

RECOMMENDATIONS FOR MULTIPLE LISTENING POSITIONS

A high-end home theater is generally designed for multiple seats. It is widely understood that the surround image will be distorted as the listener moves away from the Main Listening Position (MLP). However, the listening area is generally not exactly a circle around the MLP. Optimal surround performance can be achieved within the listening area by carefully adjusting the number and position of surround speakers according to the listening area to ensure that minimal image distortion is achieved across the listening area.

Guideline 1: Adapt the number of surround speakers to the size of the listening area.

The recommended number of surround speakers is a function of both:

- **The size of the listening area.** Most people can understand that a large room with a large listening area needs to be covered by more surround speakers.
- **The distance from the listening area to the room walls.** In other words, for a given room size, the number of speakers increases with the size of the listening area. This is due to the fact that when a listener is positioned close to a loudspeaker there is a high risk that this specific speaker becomes a dominant source, pulling most of the 3D soundstage to this unique focus point.

Think of the person sitting right next to the Left Surround speaker: in a 7-ch layout at listener level, a sound object might move down the left wall. As it moves smoothly from the L (Left) speaker to the Ls (Left Surround) speaker, the person sitting adjacent to the Ls speaker hears it sooner than anyone else because they are

closer to it; it also lingers (for them) in the speaker for longer and is too loud, also because he is right next to it. Only when it has almost completely moved on to the Lrs (Left Rear Surround) do things get back to "normal" for this person.

By contrast, imagine a room with more speakers anchoring the sound to specific locations along the wall: the sound object moves from L, to Lw, to Ls1, to Ls, to Ls2, and finally on to Lrs. With four speakers between L and Lrs, the object moves at the correct velocity and remains at about the right volume except for the short period of time it is reproduced only in the Ls. For our poor listener, it will still be a bit loud while there, but it also moves on more quickly.

Thus, the only solution is to use more loudspeakers as anchor points in the 3D sound image and make sure that the inappropriately loud effect generated by the proximity of speakers to specific seat only affects a small proportion of the entire 3D sound image. This, therefore, maintains accurate localization and an immersive experience for most of the audience. In addition, to ensure a robust surround image for all listeners, the angle between any pair of two adjacent surround speakers should not exceed 60° even for the listeners sitting on that side of the listening area. The design guide we provide to our dealers includes all the mathematics for designing these surround speakers for specific room sizes and listening areas and goes well beyond the scope of this article. But the concepts should be clear.

Guideline 2: Adapt the type of surround speakers to the shape of the listening area.

One fundamental goal in immersive home theater is to ensure that all listeners in the audience share the same experience. In other words, when an effect is mixed to the side, every listener should perceive it as coming from that side. Likewise, when an effect is mixed to the back, every listener should perceive it as coming from the back.

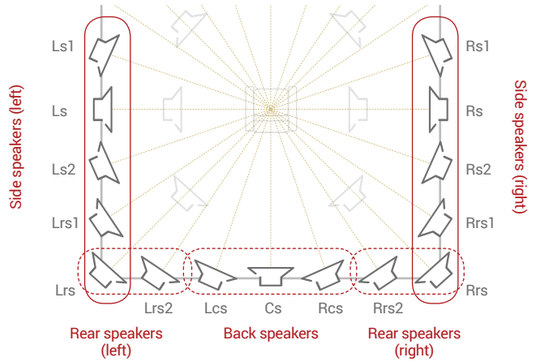
In commercial cinemas, this fundamental goal is always achieved as the objects are positioned according to the room dimensions. This is the shoe box coordinate system, in which an audio object can be positioned anywhere on the 4 walls and ceiling of the room with three Cartesian coordinates X, Y, Z defining (respectively) the left-right panning relative to the room, the front-back panning relative to the room and the up-down panning relative to the room.

Put in simple words, this is like painting on the walls. The surround speakers are mounted on the side and back walls and reproduce the objects based on the shoe box panning and their position relative to the size of the room. This shoe box coordinate system adapts to the size of the room and ensures that, even if the listening area is as large as the room itself (which is almost the case in movie theaters), anyone in the audience perceives a side effect on its side or a back effect on its back. This shoebox model is ideal in the situation where the size of the listening area is equal to the size of the room (except the area near the screen).

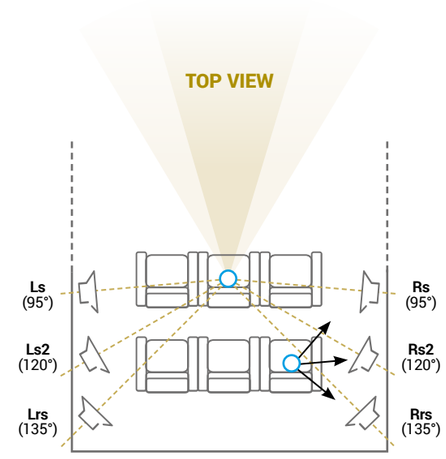
In a home environment, the listening area is smaller than the entire room and **consequently the determining factor about the positions of sound objects and loudspeakers around the listeners is no longer the room but becomes the listening area itself.**

At the same time, speaker positions should not be decided exclusively based on standard positions relative to the main listening position and completely ignoring the shape of the listening area, otherwise the obvious statement that all listeners in the listening area share the same experience may not be achieved. Let's imagine an example of how ignoring the shape of the listening area can lead to localization inconsistencies.

The "belt" of surround speakers is segmented in sub-groups: side, rear, and back speakers, each in charge of reproducing a general direction according to its name. The following drawing illustrates the surround speaker sub-groups using the nomenclature of Dolby Atmos:

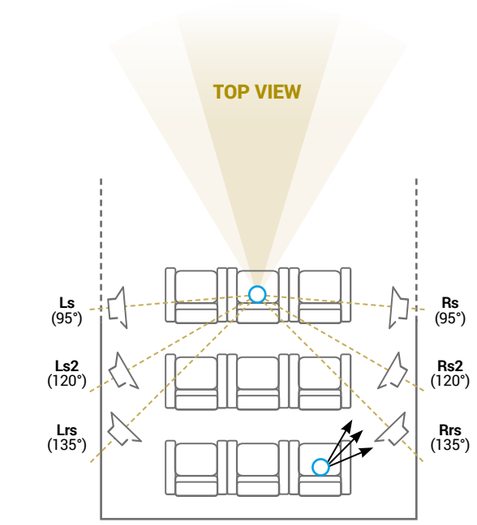


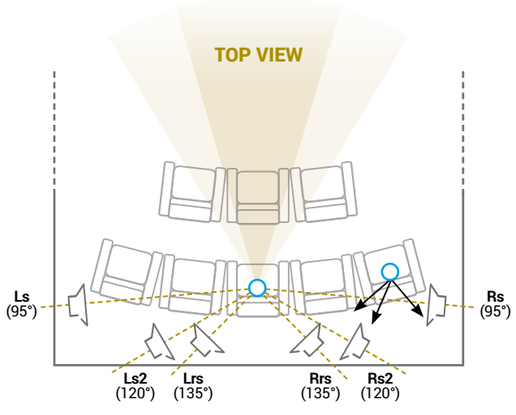
Here is an example in which the side and rear/back surround speakers work for all seats:



When the listening area is very long or very wide and, if the angles are made relative only to the reference listening point, the side or rear speakers may not be localized as intended for all seats. The two main situations to absolutely avoid are:

- When the listening area is long, avoid having a rear speaker that could be perceived as being in the front for the back row. As shown in the next example, a rear right speaker at 135° from the Main Listening Position (MLP) is positioned to the front for the person in the back-right seat.
- When the listening area is wide, avoid any situation in which a right side speaker could be positioned at the left or a left side speaker could be positioned at the right for one of the back seats. As shown in the next example, a right side speaker at 120° is located on the left when the listening area is large.



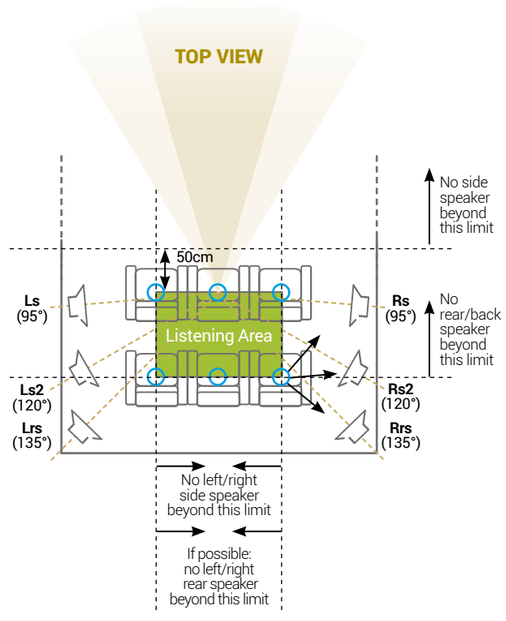


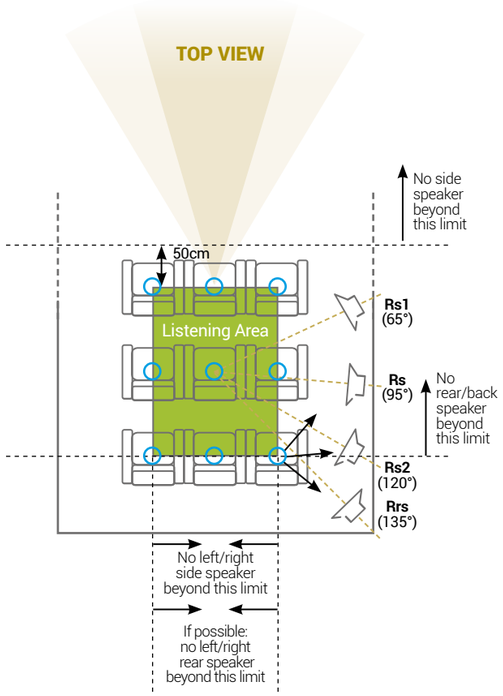
These spatial distortions stem from defining speaker placement only with regard to the MLP rather than taking the entire listening area into account.

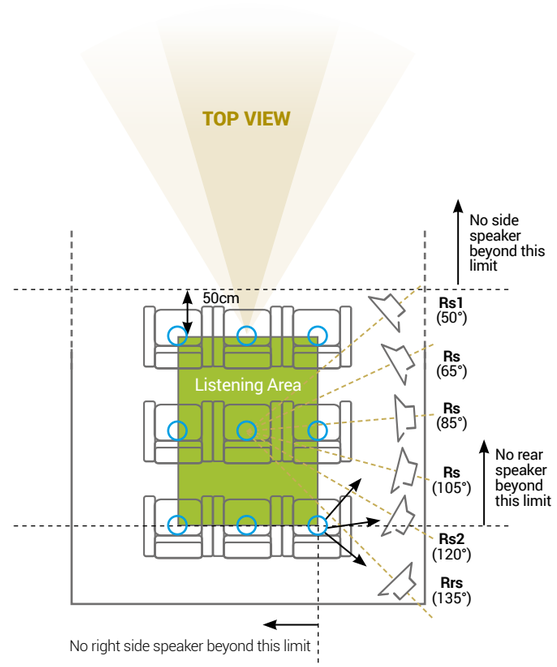
In a multi-row situation, this localization confusion is avoided for all seats if the placement of all surround speakers is adjusted relative to the listening area, the listening area being defined as the area containing all the listeners' heads.

- **All side speakers should be on the side of the listening area.** This rule ensures that none of the listeners can hear a right-side speaker from the left or a left-side speaker from the right.
- **All rear/back speakers should be behind the listening area.** This rule ensures that none of the listeners can hear a rear speaker from in front of them.
- **All rear left speakers should be heard at the left of the listening area.** This rule ensures that none of the listeners can hear a rear right speaker from the left. **The same rule applies to rear right speakers: they should be heard at the right of the listening area.** This rule may not be applicable in all situations and is less critical than the two previous rules, especially with a wide listening area relative to the room size, which requires many rear and back speakers to cover the distance between the two sidewalls.

These simple rules lead to the following limits and exclusion areas:







This concept of listening area limits is very similar to the concept of the commercial cinema “shoe box” but is applied to the listening area instead of the room. In the particular situation where the listening area is as large as the room, the exclusions limits are superposed with the room walls (side and back) and the situation is identical to the commercial cinema context: side speakers are allowed only on the side walls and rear speakers are allowed only on the back wall.

Advice: to check the relevance of a surround speaker placement, consider the back-right seat and ensure that the actual position of each surround does not conflict with the direction suggested by its name: Right side speakers should not be perceived by anyone as positioned to the Left; Rear speakers should not be perceived as positioned to the front; Rear right speaker should not be perceived as positioned to the left. Repeat the same for back left seat.

Guideline 3: For long listening areas: array the side speakers

If the angle between the three side speakers is larger than the angle between the other speakers, it is recommended adding additional Ls and Rs speakers in an array to achieve more uniform loudspeaker coverage. This array should be achieved with constant power signal distribution. (Example: a pair of Rs speakers should each be set to -3 dB so their combined output power adds to the correct value; the Altitude handles this detail for you automatically.)

Arraying speakers improves the coverage of the listening area, but at the expense of a spatial distortion of audio objects both in trajectory velocity and apparent object size.

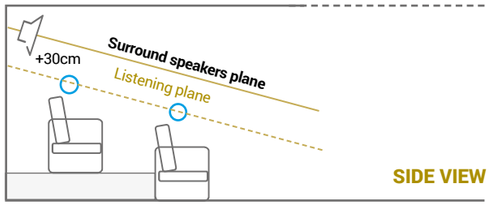
Guideline 4: Horizontal and vertical head clearance.

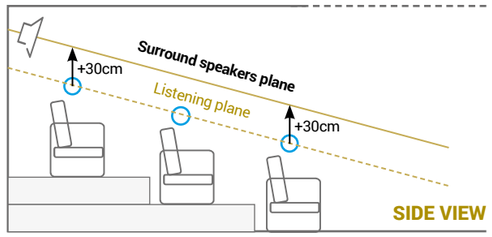
In all situations with multiple listeners, it is important to avoid any form of shadowing where one listener's head would occlude a loudspeaker for another listener. When a loudspeaker is occluded, both the tonal balance and the localization of sound are negatively affected in a dramatic way. This negative impact is uncontrolled as the listeners are free to move their heads. Head clearance is easily achieved by elevating the surround speakers slightly above the listening plane (the plane that intersects all listeners' ears).

The listening plane is different from the line-of-sight that is used to resolve visual occlusion relative to the screen. In the common situation of raised back seating rows, the listening plane is tilted toward the front. This method is similar to the one used in 7.1 home theater systems except that the plane of surround speakers is only elevated by 30cm/1ft (instead of 60cm/2ft). Reducing the height of the bed speakers leaves more room for height speakers and also avoids having all the sound significantly above ear level, which would result in an all-above-the-head presentation that conflicts with the ideal goal of achieving full spherical immersion.

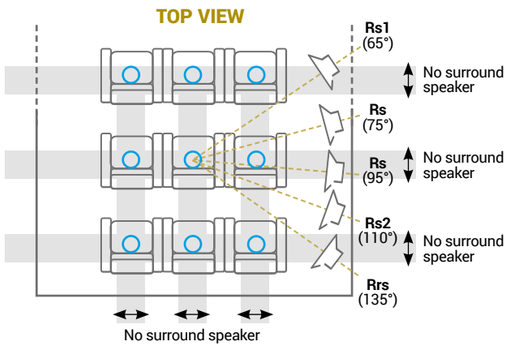
The trick is to minimize head occlusion of the sound while maximizing the differentiation between the bed channels around you and the height channels above you. Elevating surround

speakers is also extremely important when the listening area is large compared to the room size and when listeners can sit close to the nearest surround speaker, which will appear as a focused source in the 3D sound stage. Elevating the surround speakers reduces the seat-to-seat differences in speaker distance and level, resulting in a more uniform surround reproduction for all seats.





In order to avoid an “all-above-the-head” sound reproduction with limited immersion, the surround speakers may only be elevated by 30cm (1 foot) and the closest surround speakers can still appear as undesired focus points. Placing the surround speakers so they are not perfectly aligned with listeners’ heads can further reduce this effect.



Guideline 5: Recommended speaker arrays to maximize speaker usage in all formats.

Dolby Atmos is currently the only format to provide up to 34 discrete speaker feeds, providing a robust 3D audio image not only at the main listening position (MLP) but also across a sensible listening area around the MLP. Other formats such as Auro-3D, DTS:X and legacy multichannel recordings provide a lower channel-count, limited to 4 surround channels. (The new DTS:X Pro format offers 30.2 discretely-rendered channels and spatial resolution comparable to Dolby Atmos.)

As a result, in situations with more than one listener, it is necessary to array additional speakers to ensure that the surround imaging obtained at the MLP is reasonably preserved across the listening area. The number of physical surround channels follows Guideline 1 and the array topology follows Guideline 2 to ensure that side channels feed all side speakers and rear channels feed all rear speakers relative to the shape of the listening area.

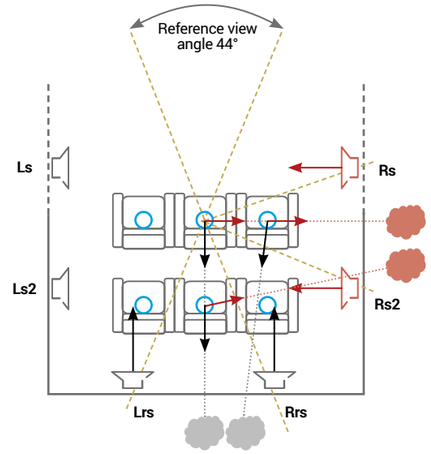
The format correspondence to array surround speakers is provided in the following table:

Dolby Atmos	Auro 3D	DTS:X 7.1.4	DTS:X 30.1
Ls1	Ls	Ls/Lss	Lss
Ls	Ls	Ls/Lss	Lss
Ls2	Ls	Ls/Lss	Ls
Rs1	Rs	Rs/Rss	Rss
Rs	Rs	Rs/Rss	Rss
Rs2	Rs	Rs/Rss	Rs
Lrs1	Ls	Ls/Lss	Ls
Lrs	Lb	Lsr	Lsr
Lrs2	Lb	Lsr	Lsr
Rrs1	Rs	Rs/Rss	Rs
Rrs	Rb	Rsr	Rsr
Rrs2	Rb	Rsr	Rsr
Lcs	Lb	Lsr	Lsr
Rcs	Rb	Rsr	Rsr
Cs	-	-	Cs

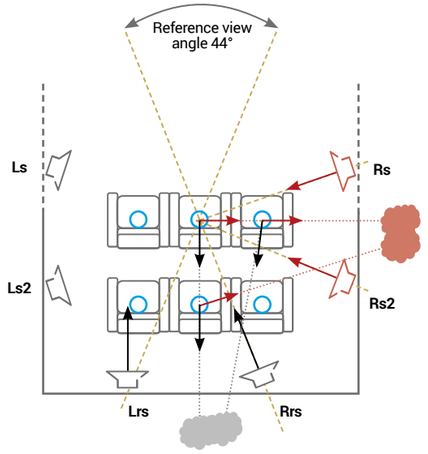
Guideline 6: Optimal speaker orientation

Several speaker orientation methods are possible depending on the project requirements and budget.

Flush or shower mounting is recommended in projects requiring simple speaker integration without complex mounting systems. The localization and immersive experience will be compromised for listeners sitting on the side of the main listening position. It is easily understood in the situation where a pair of surround speakers, either a pair of sides (red) or a pair of rears (black), reproduce an identical signal forming a sound source exactly half way between the 2 active speakers. Because of the directivity of the surround speakers, a listener sitting toward one speaker would receive more level from this particular speaker resulting in a shift of the localization toward this speaker. This speaker orientation method is very sensitive to the room acoustics as



TOP VIEW



most of the speaker energy is projected directly to the opposite wall, maximizing unwanted lateral reflections and reverberation.

Pointing speakers toward the MLP is recommended if the integration allows for mounting system or if the speakers are pre-angled. This speaker orientation ensures best possible localization, immersion and tonal balance at the MLP while minimizing localization shifts for side seats. This speaker orientation method provides a result that is (slightly) less dependent on room acoustics as the energy projected out of the listening area is minimized.

In the particular case of surround speakers, **cross-firing** method is almost equivalent to pointing speakers toward the MLP. As surround speakers are located close to ear level and as the MLP is somewhere in the middle of the listening area, a speaker pointing toward the opposite seat will also be pointed very close to the MLP.

In future articles in this series, we will present our recommendations for the use and placement of both Wide and Height channels (by which we mean all the channels above you, regardless of what the various formats call them within their own nomenclature).

Recommended Loudspeaker Positions for Wide and Upper Loudspeakers

Mutrox / Bower & Wilkins ISE 2018 Active demo

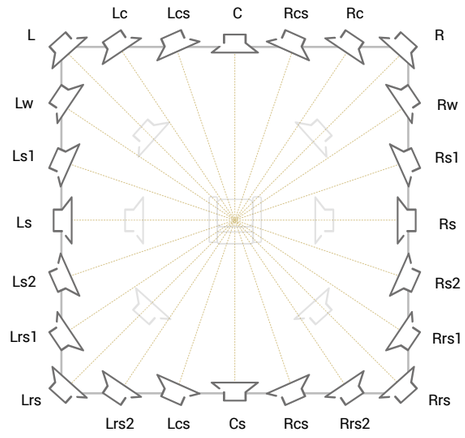
WIDE & UPPER LOUDSPEAKERS

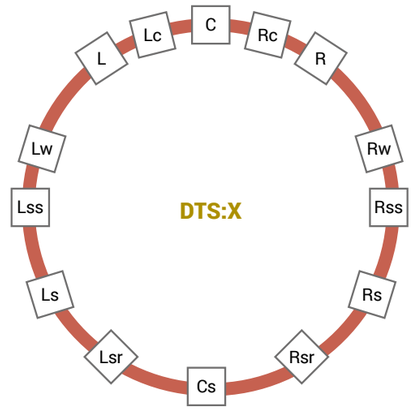
RECOMMENDATION FOR WIDE SPEAKER PLACEMENT

We now get to what might seem to be the simplest category of speakers to place: the Wide channels. Recall that they were introduced in an effort to fill the rather large gap between the screen channels and the front-most of the surround channels. Seems straightforward, right?

Dolby and DTS both recommend placing the front wide speakers on the listening plane at ±60° relative to Center.

DOLBY ATMOS





So, it would seem we have some rare agreement. Good.

But remember that all these immersive audio speaker layouts were designed with a single listening position in mind (if only to simplify the problem for those designing the systems).

Guidelines for high end home theater

Again, the purpose of the front wide speakers is to fill the large gap between the screen speakers and the surround speakers. This area is usually a problem for multiple reasons:

- Human localization is not very good for front-side directions.
- Sound images produced by a pair of speakers usually work better when the head of the listener is pointing toward the center of the pair, which is not possible in a home cinema context.
- The angle between the screen speakers (typically ±22°-30°) and the side speakers (typically ±90°-100°) is extremely wide and the resulting phantom sound images are blurred and unstable.

In this section, it is assumed that the L/R speakers are optimally placed relative to the screen and that the surround speakers are optimally placed relative to the listening area. Therefore, the front wide speakers should be placed to optimize the bridge between the L/R speakers and the first surround speakers (the closest surround to the screen), regardless of the screen and the listening area.

This is achieved by placing the front wide speakers at the median angle between the L/R speakers and the corresponding first surround speaker. The median angle is defined as the angle that divides the distance between L/R speakers and the first surround speakers into two segments of equal length.

Think of stretching a tape measure between the Left speaker and the front-most Left Surround. Draw a line from the main listening position through the halfway point on the tape measure and extend it to the wall. That's the median angle.

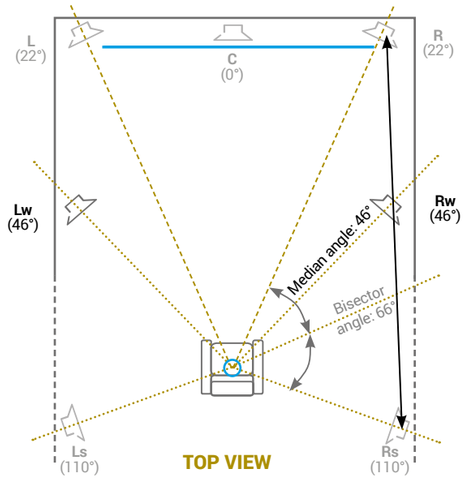
The median angle is preferred over the bisector angle that divides the angle between the L/R speakers and the first surround speaker into equal angles. Despite the bisector angle being more intuitive, the median angle has several advantages:

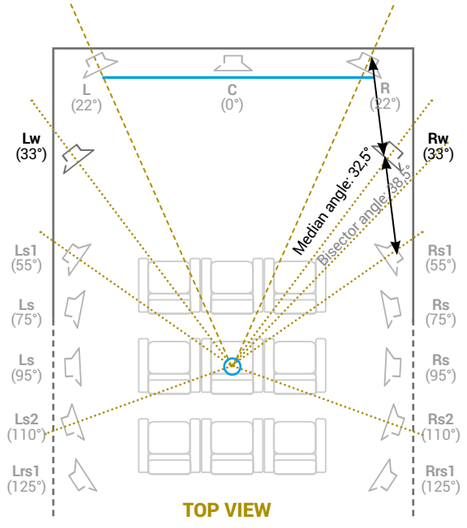
- The median angle rule does not position the wide speakers too close to the surrounds
- The median angle rule is sensitive to the actual distance between the L/R and the surround speakers. For instance, for a given L/R angle, the front wide channels are optimally placed based on the actual distance between the listening area to the screen, as opposed to a fixed position is the case for the bisector angle rule.

The rule of the median angle is illustrated in the following sections for various L/R and surround angles.

Normal L/R angle (reference view angle of ±22°)

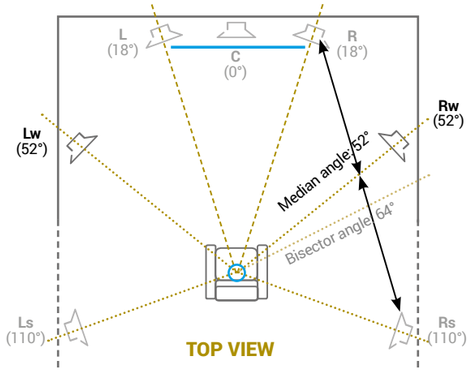
The following figures illustrate the position of the front wide speakers for a normal L/R angle of ±22° and two situations: few surround speakers or many surround speakers. The median angle method provides a more intuitive position than the bisector angle method.

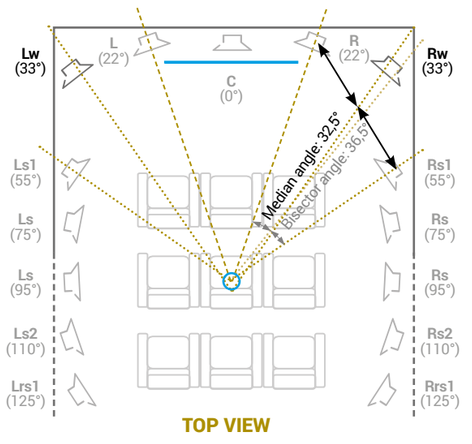




Narrow L/R angle

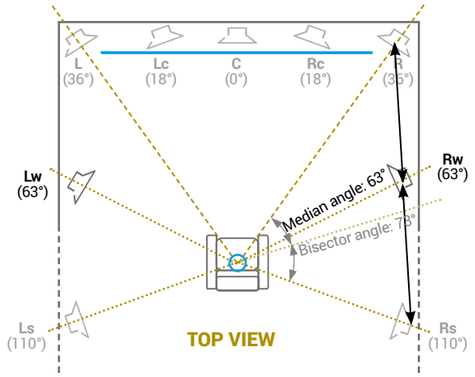
The following figures illustrate the position of the front wide speakers for a narrow L/R angle of ±18° and two situations: few surround speakers or many surround speakers. Again, the median angle method provides a more intuitive position than the bisector angle method.

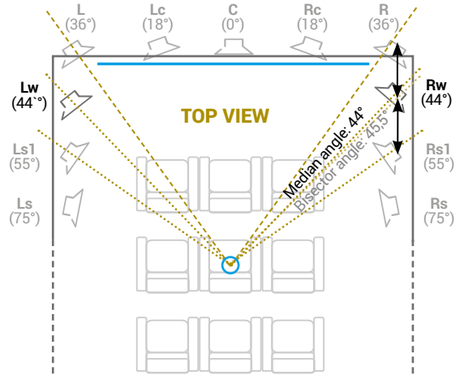




Wide L/R angle

The following figures illustrate the position of the front wide speakers for a normal L/R angle of ±36° and two situations: few surround speakers or many surround speakers. Again, the median angle method provides a more intuitive position than the bisector angle method.



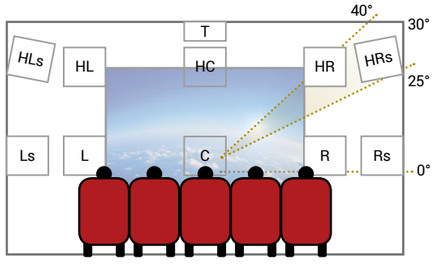


RECOMMENDATION FOR UPPER SPEAKER PLACEMENT.

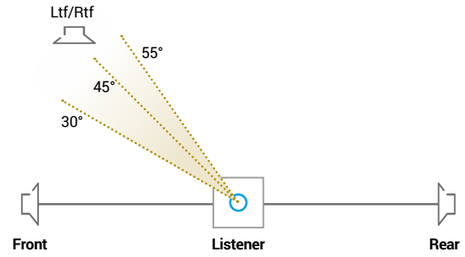
Nowhere is the disparity of speaker placement recommendations between the three immersive audio formats more clear than for the upper/height/top channels. Yet, even here, carefully thinking through the goals of all three formats for immersion can lead to some specific placement recommendations that work well in all three contexts (especially with the help of Trinnov's 3D Remapping technology).

Guidelines for one listening position

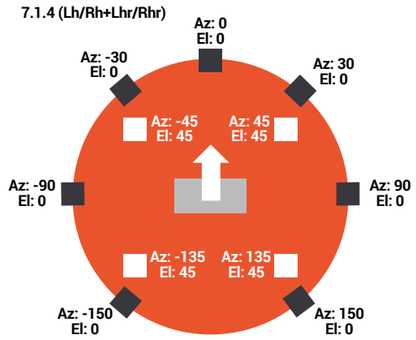
It is helpful to review the specific recommendations provided by the three formats at this point.



AURO-3D



DOLBY-ATMOS



DTS:X

It is important to note that the elevation angles given by the three formats cannot be compared directly since they use different coordinate systems.

- Auro-3D and DTS:X use a polar coordinate system in which the elevation angle is measured relative to the horizontal plane; more precisely, it is the angle between the speaker direction and the projection of the speaker direction to the horizontal plane. The polar coordinate system is ideal to describe speaker layouts composed of several circular layers. The elevation is provided independently of the horizontal angle (azimuth).
- Dolby Atmos uses a side view model in which the 3D direction is projected on the median plane (the elevation is measured from the 2D side view of the room). This coordinate system is more convenient for 2D planning as it can be measured directly on a 2D plan. The downside is that to locate precisely a loudspeaker, both azimuth and elevation need to be used together.

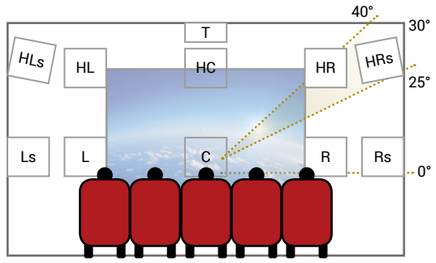
In order to be compared, polar coordinates and shoe box (x.y.z) coordinates can be mutually converted using projection methods. This distinction between polar and side view is only applied to the elevation angle. In the case of horizontal angles, the polar azimuth angle corresponds to the top view horizontal angle.

The bottom line: be careful when comparing recommended angles since all angles are not, in fact, the same.

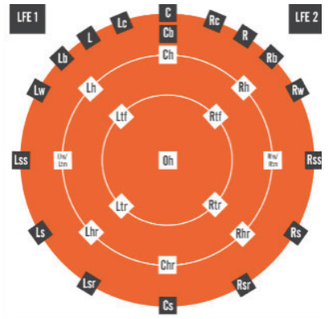
Two upper layers: Height vs Top speakers

All formats have some upper speakers with smaller elevation angles and other upper speakers with higher elevation angles. In order to differentiate these two categories (or layers) of upper speakers, all three formats share the same convention:

- upper speakers with smaller elevation angles are called "height" speakers.
- upper speakers with higher elevation angles are called "top" speakers.



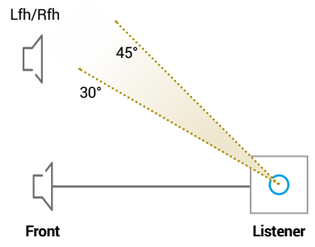
AURO-3D / height speakers



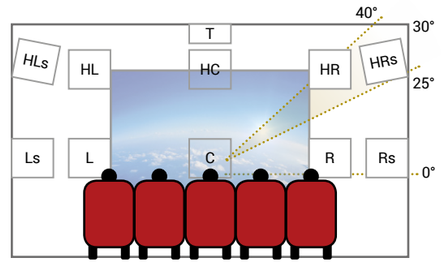
DTS:X / height and top speakers

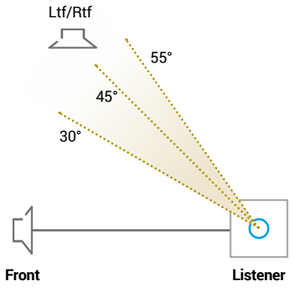
Ceiling vs wall speakers in Auro-3D

Auro-3D recommends an elevation angle between the lower layer and the upper layer within the range of 25° to 40°, with 30° being optimal. This range allows a sound image to be built between the two layers. This applies even if the ear level speakers are elevated by 5° to achieve head clearance.

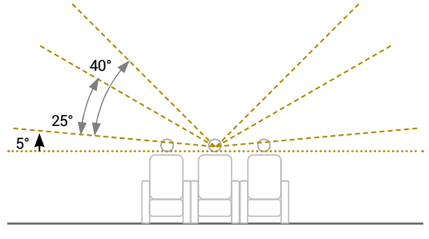


DOLBY-ATMOS / height speakers

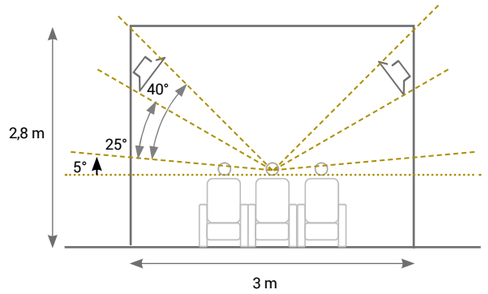


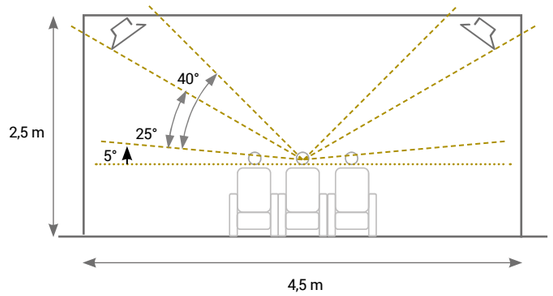


DOLBY-ATMOS / top speakers



Depending on the size of the room (width and ceiling height) the speaker will be located on either the side walls or the ceiling. With normal home width and ceiling height, the speakers will most probably be located on the ceiling.





GUIDELINES FOR MULTIPLE LISTENING POSITIONS

Guideline 1: Adapt the number of upper speakers to the length of the listening area.

The recommended number of upper speakers is a function of:

- The length of the listening area. It is fairly intuitive that a long listening area needs to be covered with more upper speakers.
- The distance from the listening plane to the ceiling. In other words, the number of speakers increases as the listeners get closer to the ceiling. This is due to the fact that when a listener is positioned close to a loudspeaker there is a high risk that this specific speaker becomes a dominant source, pulling most of the 3D soundstage to this unique focus point. The only solution is to use more loudspeakers as anchor points in the 3D sound image and make sure that the focus effect generated by the proximity speakers only affects a small proportion of the entire 3D sound image therefore maintaining accurate localization and immersive experience for most of the audience. In addition, to ensure a robust height image for all listeners, the angle between a pair of 2 successive upper speakers should not exceed 60° even for the listeners sitting on the front or back of the listening area.

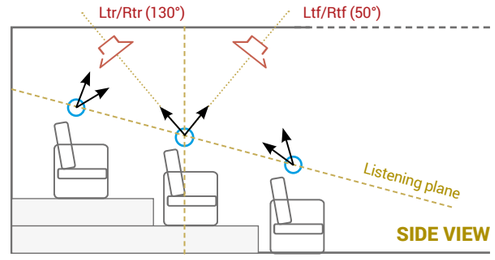
The thinking here is much like that of the person who is sitting too close to the Ls speaker as outlined in previous articles. If you are too proximate to a particular speaker, its sound will dominate what you hear and distort your perception of the soundfield. The solution is to anchor objects to specific locations along the ceiling by having more ceiling speakers, depending less on phantom imaging. The increased spatial resolution is enjoyed by everyone in the room.

Guideline 2: Adapt the position of upper speakers to the shape of the listening area.

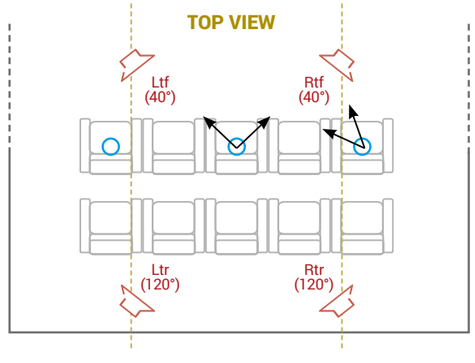
One fundamental goal in immersive home theater is to ensure that all listeners in the audience share the same experience. In other words, when an effect is mixed to the front height, every listener should perceive it from the front height. Likewise, an effect is mixed to the back height, every listener should perceive it from the back height. This obvious statement can be easily missed if speaker positions are decided only based on the reference position and ignore the length of the listening area.

When the listening area is very long or very wide and if the angles are made relative only to the reference listening point, the upper speakers may not be localized as intended for all seats. The two main situations to absolutely avoid are:

- When the listening area is long, avoid placing an upper front speaker such that it could be perceived in the rear for the front row, and avoid placing an upper rear speaker that could be perceived in the front for the back row. As shown in the next example, a top front speaker at 50° and a top rear speaker at 130° are respectively positioned to the back for the front row and at the front for the back row.



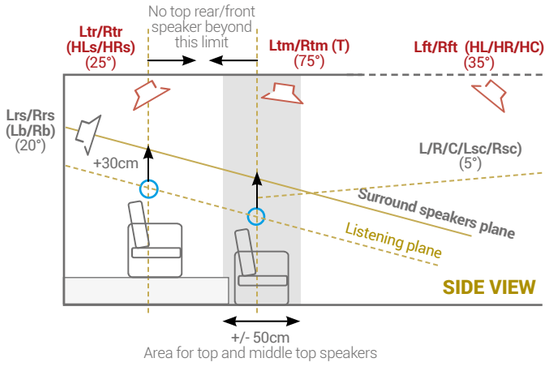
- When the listening area is wide, avoid placing an upper right speaker such that it could be perceived in the left or an upper left speaker could be perceived at the right for one of the side seats. As shown in the next example, a top right side speaker is located on the left when the listening area is large.



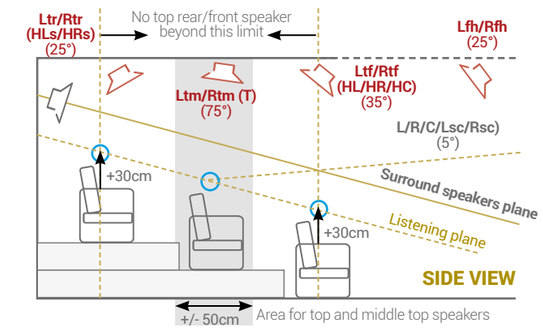
As a result, in a multi-row situation, the localization confusion is avoided for all seats if the placement of all upper speakers is adjusted relative to the listening area according to the following guidelines:

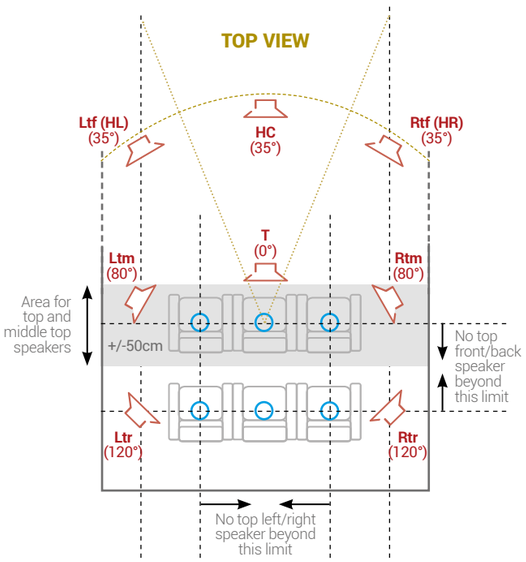
- All upper front speakers should be at the front of the listening area. This rule ensures that none of the listeners can hear an upper front speaker as coming from behind.
- All upper rear speakers should be at the rear of the listening area. This rule ensures that none of the listeners can hear an upper rear speaker as coming from the front. This guideline may not be achievable if the back row seats are placed against the back wall. In this case it is preferable to exclude the back row from this rule.
- It is preferred that all upper left speakers should be at the left of the listening area. This rule ensures that none of the listeners can hear an upper left speaker as coming from the right. However, in the situation where the listening area is almost as wide as the screen, this rule could lead to an excessive distance between upper left and upper right speakers, resulting in a compromise at the main listening area. In this case, it is preferable to exclude the far left seats from the rule.
- All upper right speakers should be at the right of the listening area. This rule ensures that none of the listeners can hear an upper right speaker as coming from the left. As for the point above, the far right seats can be excluded from the rule to avoid excessive distance between upper left and upper right speakers.

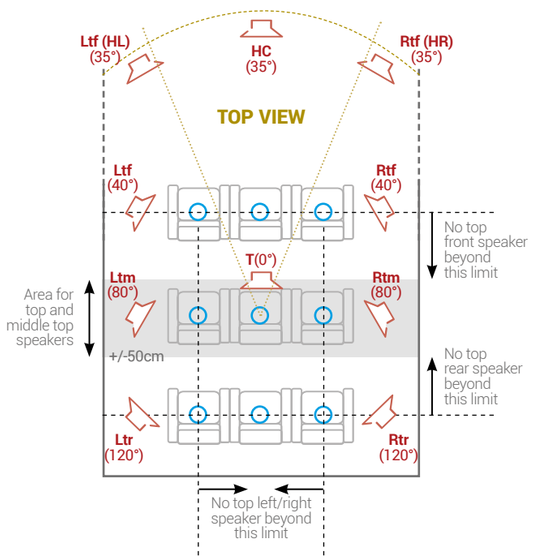
These simple rules lead to the following limits and exclusion areas:



In the case of a three-row listening area, this simple rule leads to the following limits and exclusion areas:

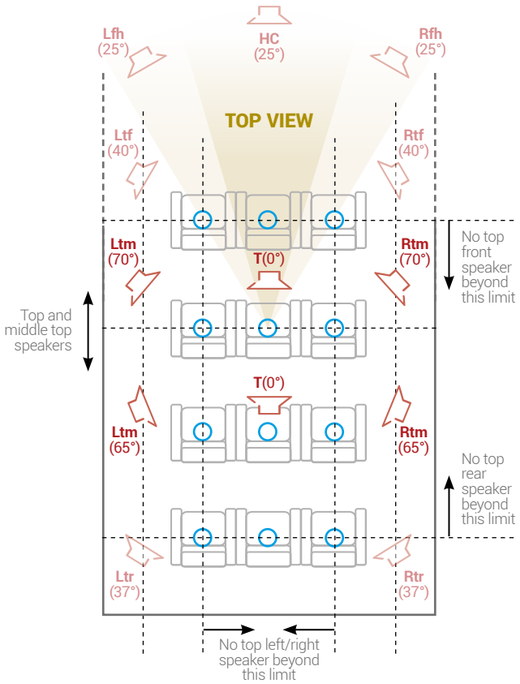


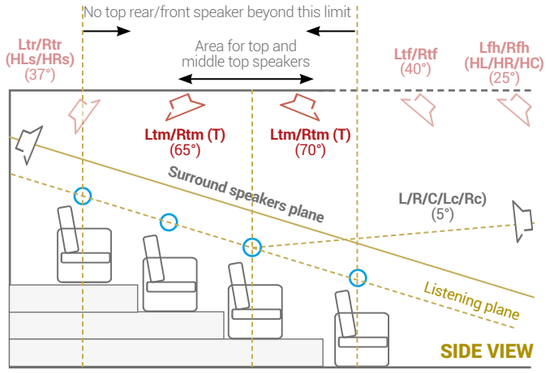




Guideline 3: Array Top speakers for long listening areas.

When the listening area is long, the angle between the top speakers (front top, top, middle top and rear top) can become significantly larger than the angle between the other speakers. In this case, it is recommended to array the top and/or the middle top speakers to achieve more uniform loudspeaker coverage. This array should be achieved with constant power signal distribution. (Again, the Altitude[32] handles this detail automatically.)

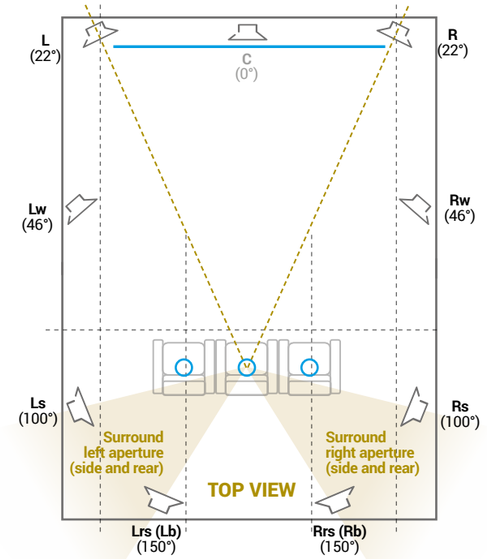


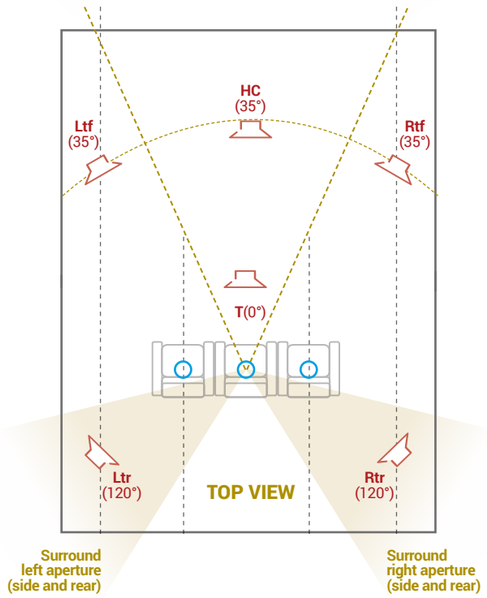


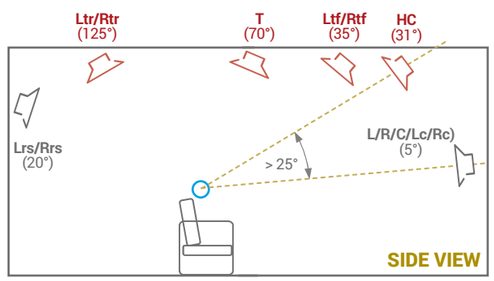
Guideline 4: Achieve consistency between ear-level and upper-layer.

Even if the different speaker groups need to be defined according to their function and their positions need to be specifically optimized, it is important that the upper layer remains related to the ear-level layer to achieve a single coherent 3D soundstage. This is a requirement for Auro-3D where the upper layer should be very similar to the lower layer. But, by design, there are more ear-level speakers than upper-speakers. Consequently, it is not possible for each ear-level speaker to be associated with a corresponding upper-speaker. The consistency between speaker layers is achieved within groups of speakers that should cover the same horizontal aperture:

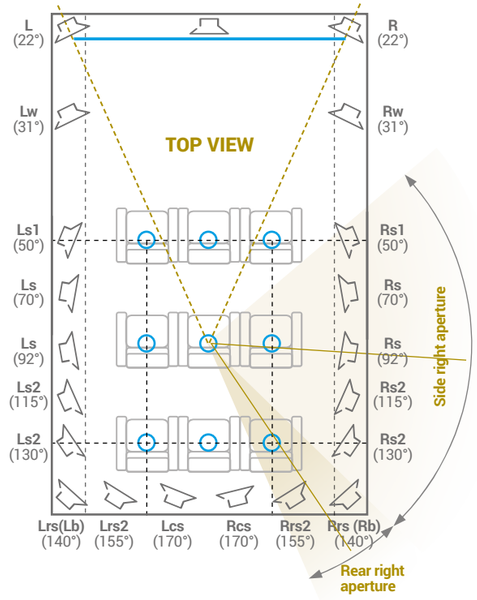
- In a simple configuration where there are only two top rear speakers, they should be placed near the center of the aperture formed by the surround speakers. In such a simple configuration front height speakers are not available and the top front are used to also reproduce Auro front height speakers, provided the elevation angle between the L/C/R speakers and the Ltf/HC/Rtf is greater than 25° and does not exceed 40°.

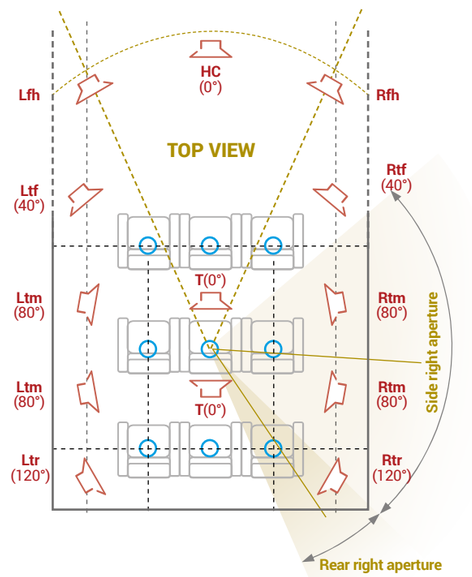


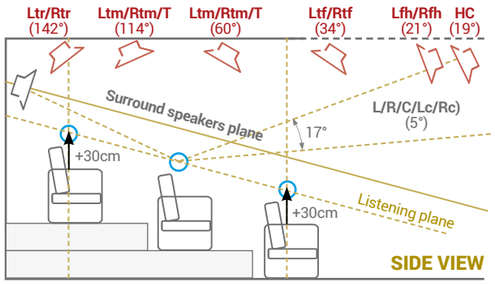




- In more complex configurations, the top middle speakers should form a layer on top of the side speakers, therefore the top middle speakers are placed within the horizontal aperture of the side speakers. Likewise, the top rear speakers should form a layer on top of the rear speakers; therefore the top rear speakers are placed within the horizontal aperture of the rear speakers. In such complex configurations, front height speakers are available and should be placed just above the screen provided the elevation angle between the L/C/R speakers and the Lfh/HC/Rfh is greater than 15° and preferably greater than 20°.







Guideline 5: Recommended speaker arrays to maximize speaker usage in all formats.

Dolby provides up to 10 discrete upper channels; Auro-3D provides 6 discrete upper channels; DTS:X provides 4 discrete upper channels; finally DTS:X Pro will support as many as 13 discrete upper channels. As a result, in situations with more than one listener, it is necessary to array additional speakers to ensure that the surround imaging obtained at the MLP is reasonably preserved across the listening area. The array topology follows Guideline 2 to ensure that side channels feed upper speakers in a relevant way relative to the size and shape of the listening area.

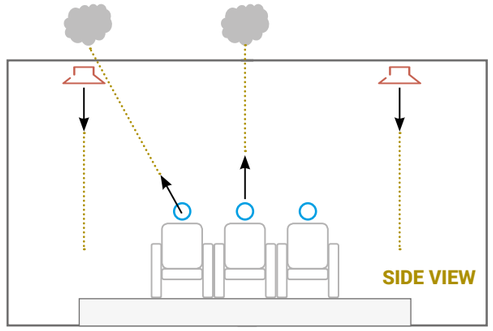
The format correspondence to array speakers is provided in the following table:

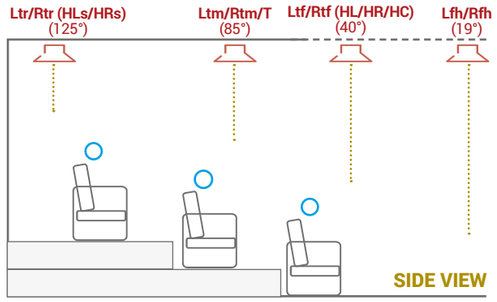
Dolby Atmos	Auro 3D	DTS:X 7.1.4	DTS:X 30.1
Lfh	HL	Lh / Ltf	Lh
Rfh	HR	Rh / Rtf	Rh
Ltf	HL	Lh / Ltf	Ltf
Rtf	HR	Rh / Rtf	Rtf
-	HC	-	Ch
Ltm	-	-	Lhs / Ltm
Rtm	-	-	Rhs / Rtm
-	T	-	Oh
Ltr	HLs	Lhr / Ltr	Ltr
Rtr	HRs	Rhr / Rtr	Rtr
Lrh	HLs	Lhr / Ltr	Lhr
Rrh	HRs	Rhr / Rtr	Rhr
-	-	-	Chr

Guideline 6: Optimal speaker orientation

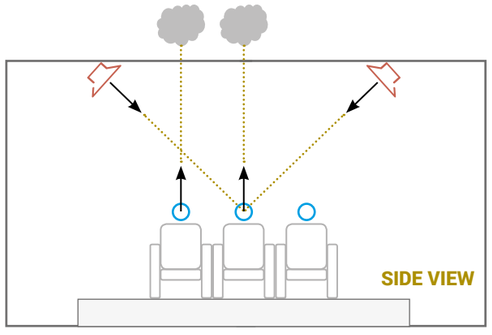
Several speaker orientation methods are possible depending on the project requirements and budget.

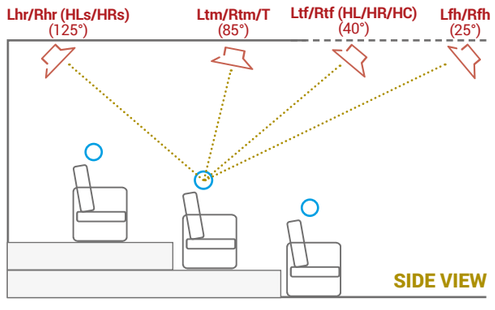
Flush or shower mounting is recommended in projects requiring simple speaker integration without complex mounting systems. The localization and immersive experience will be compromised for listeners sitting on the side of the main listening position. It is easily understood in the case where an upper left and upper right speaker reproduce an identical signal forming a sound source exactly half way between these two speakers. Because of the directivity of the speakers, a listener sitting at the left would receive more level from the upper left speaker than the upper right speaker resulting in a substantial shift of the localization toward the left.



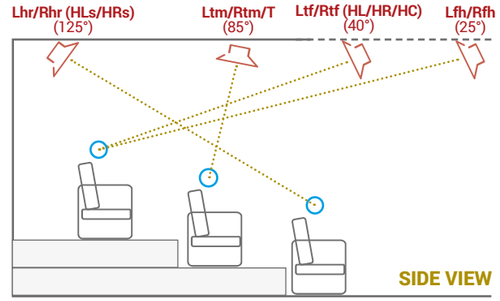


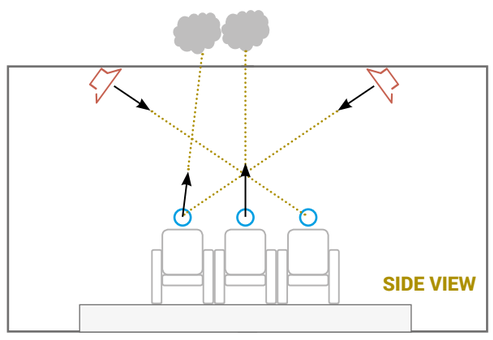
Pointing speakers toward the MLP is recommended if the integration allows for mounting system or if the speakers are pre-angled. This speaker orientation ensures best possible localization, immersion and tonal balance at the MLP while minimizing localization shifts for side seats.





Cross-firing is recommended to achieve best overall localization and immersion for all seats at the expense of a slight compromise at the MLP. It is easily understood using the example where upper left and upper right speakers form a sound source exactly these speakers. Because of the distance of the upper left and right speakers, a listener sitting at the left would be closer to upper left speaker shifting the source toward the left but at the same time this listener would be more on axis with the upper right speaker and more off-axis with the upper left speaker resulting in more level to the right which is shifting back the source toward its original position. The sound image is stabilized within the listening area. This cross-firing method requires selecting speakers based on their off-axis performance.





As mentioned in previous articles, having angled mounting such as depicted here is usually not practical. But there are speakers available with angled baffles that can accomplish at least some of the same effect as angling the speakers as shown in these diagrams. The difference in both imaging and in sound quality is significant. Very few speakers perform well at such extreme off-axis angles. The goal should be to have each speaker's best sound aimed into the listening area.

CONCLUSION

Truly immersive audio is made possible by modern, object-oriented soundtracks that provide a great deal of artistic freedom and potential spatial resolution. While the technologies and specific recommendations seem confusing at first, we hope we have been able to provide a way of thinking about your project that helps you decide what is best for your situation.

There are really just a handful of fairly common-sense rules you need to keep in mind:

1. Think about speaker placement relative to the listening area, not just the main listening position. Everyone in the room is important and the goal is a shared experience.

2. Larger rooms probably need more speakers; however, and less intuitive, as the listening area becomes larger relative to the room, you definitely need more speakers.

3. Sound mixed to the front should be perceived as being in front of the entire audience; likewise, for the back, and the sides. This simple idea leads to “exclusion zones” beyond which a certain speaker should not be placed.

4. Just as with sight lines for projections, “listening lines” to avoid head occlusion are also important. Multi-row theaters usually benefit from risers to help address both considerations.

5. Maximizing the difference between listener-level and upper channels, consistent with the idea of listening lines mentioned above, will increase the immersive experience.

MILESTONES

15 Years of Immersive Audio Evolution.

2001

FIRST RESEARCH IN 3D SOUND

Laborie, Montoya and Bruno create and test a working high-spatial resolution 3D audio recording and playback chain.

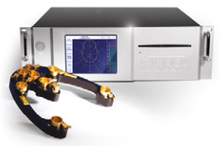
2000

ircam Centre Pompidou

THE ORIGINS

The forthcoming Trinnov founders Arnaud Laborie, Sébastien Montoya, and Remy Bruno join forces to focus on research in 3D sound.

2004



FIRST PRODUCT: 5.1 RECORDING SOLUTION

Trinnov presents the Optimizer technology as a surround monitoring solution at the 118th AES Convention in Barcelona.

IOSONO AND SONIC EMOTION

First commercial application of Wave Field Synthesis (Cinema & PA). First commercial application of Object-based audio (Caruso project Europe).

2003

AUDIO A ES

FOUNDATION OF TRINNOV

Trinnov stands for Tri-nnovation

FIRST AES PAPER

Trinnov presents the first of many scientific papers to the 114th AES Convention in Amsterdam: "A New Comprehensive Approach of Surround Sound Recording", preprint 5717.

2005

OPTIMIZER MONITORING SOLUTION

Trinnov presents the Optimizer technology as a surround monitoring solution at the 118th AES Convention in Barcelona.

AURO FORMAT 2+2+2 NHK FORMAT 22.2

At an AES workshop presented by Wilfried Van Baelen and co-organized with Trinnov's Arnaud Laborie and HK's Kimio Hamazaki, Auro first showed their 2.2.2 format. NHK also presented a 22.2 channel proposal for their 8K UHDTV standard (super Hi-Vision).

2008

20th Century Fox · BBC · ORF · francetélévisions · McGill · NHK · ICI Radio-Canada

THE OPTIMIZER GETS ADOPTED BY THE PRO AUDIO INDUSTRY

Post-production facilities: Fox Studios (LA), Radio France (Paris) France Television, SWR, ZDF, IRT (Germany), BBC (UK), RTBF (Belgium), Radio Canada, TSI (Switzerland), NRK (Norway), ORF (Austria) Globo TV (Brazil)... Music studios: McGill University, Vienna Fine Arts Academy (Austria), Tonstudio Beusch (Switzerland)...

Sherwood

FIRST OEM PRODUCT. PARTNERSHIP SHERWOOD NEWCASTLE R-972

The first consumer product to incorporate the Optimizer, in a scaled-down version, received high praise from reviewers and audiophiles for its exceptional sound quality.

2010

TRINNOV ST2 HIFI

At the Munich High-End show, the ST2-HiFi processor makes its debut, bringing Optimizer speaker/room technology for the first time to high-end stereo enthusiasts.

TRINNOV ST2 & MC PRO

At the 128th AES convention in London, the ST2 and MC Pro are launched, making the Optimizer available to a wider range of pro audio applications including music, radio, TV and film production and post-production.

2012

TRINNOV MAGNITUDE

As home theaters become more sophisticated, Trinnov leads the path towards high channel count systems beyond 7.1. The Magnitude provides up to 32 channels for systems with arrays, multi-amplified speakers and multiple subwoofers.

IMMSOUND PARTNERSHIP

Spanish startup ImmSound launches its object-based 3D cinema format with 30 screens, each based around a 24-channel Trinnov processor. The startup is acquired by Dolby in 2012, and its technology is incorporated into the Dolby Atmos program.

2015

TRINNOV ALTITUDE32

With the launch of Dolby Atmos, all processors are limited to 7.1.4 channels. The Altitude32 shatters this limitation, establishing a new standard for high-end home theaters with its capability of rendering up to 32 discrete Atmos channels.

AURO 3D AUDIO · DOLBY ATMOS

DOLBY ATMOS & AURO 3D

In 2015, at the ISE show in Amsterdam, the Altitude32 demonstrates its cutting edge capability, as the first processor able to demonstrate both the Dolby Atmos and Auro-3D formats.

2013

TRINNOV OVATION

Trinnov launches its highly successful digital cinema processor, taking cinema sound to a new level with Optimizer technology.

2016

TRINNOV AMPLITUDE8

The ideal complement to the Altitude32. Dual 4-channel amplifiers on a single chassis, the Amplitude8 delivers a continuous 500W at 2 ohms with all channels driven. Gain matched to Altitude processors, it provides up to 8 dB improvement in signal-to-noise and dynamic range.

JBL SYNTHESIS SDP-75

JBL Synthesis and Trinnov partner to produce the top of the line Synthesis processor. Manufactured on an OEM basis by Trinnov, the SDP-75 incorporates most of the Altitude32's capability, for dedicated use with systems utilizing Synthesis loudspeakers.

2017

ALTITUDE16 & AMPLITUDE8M

Trinnov technology and sound quality become available to a wider audience with the introduction of the Altitude16. With performance essentially identical to the Altitude32 but limited to 16 channels, the Altitude16 makes Trinnov performance more affordable. The Amplitude8m is its ideal companion, an 8-channel power amplifier.

dts X · roon

DTS:X & ROON

After being used by DTS as the developmental platform for DTS:X, the Altitude32 becomes the first surround preamplifier to support DTS:X. The Altitude32, Altitude16 and Amethyst are all upgraded to fully-certified Roon Endpoints, providing the best possible music streaming experience. Existing Altitude owners upgrade to Roon through a free download.

2018

Dante

TRINNOV MC PRO HCC

Trinnov's multichannel Optimizer and monitoring solution becomes more versatile with the addition of audio over IP through Dante, Ravenna and AES67.

ALTITUDE48 EXT

Further widening the gap between the Altitude and competitive processors, the Altitude48ext expands the Altitude32's capability to the maximum 24.x.10 channels of Dolby Atmos, and as many as 48 uniquely rendered channels, even up to 64 processed channels.

2019

TRINNOV OVATION2

The next generation of cinema processors further elevates audio performance in commercial cinema installations.

IMAX ENHANCED · dts X

DTS:X PRO & IMAX ENHANCED

The Altitude32 and Altitude16 are the first processors to support DTS:X Pro, with the Altitude32 able to discretely render the full complement of 30.2 channels. A free download provides the upgrade to all existing Altitude owners. IMAX Enhanced, with capable displays, enables users to benefit from the enhancements of this dedicated software.

TRINNOV | CINEMA | HIGH•END | PRO•AUDIO | R•D | OEM

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