

Immersive Audio - unified 3D speaker layouts for multiple listeners

ISE 2017 – Feb 8, 2016

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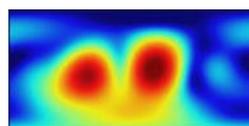
Arnaud Laborie



- Co-founder and CEO at Trinnov Audio
- Pioneer in **3D sound** and **acoustic correction**
- 15 years of experience in Research and Development of 3D Audio (recording, reproduction and processing)
- Co-designer of the first high-spatial-resolution audio chain in 2001.



3D recording



3D transformation



3D reproduction

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Arnaud Laborie



- Author of over 20 papers (including AES papers)
- 5 inventions about 3D audio and owner of 48 patents.
- Designer of innovative audio products used:
 -  in over 800 studios (incl. Film post and Blu-Ray mastering)
 -  in over 1000 commercial cinemas
 -  in many high-end home environments
 -  in licensed consumer products



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Learning Objectives

- **Immersive audio formats and 3D speaker layouts**
- **Additional constraints for multiple listeners**
- **Building 3D speaker layouts for multiple listeners**
- **Apply guidelines in a practical use case.**

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Immersive Audio: unified 3D speaker layouts for multiple listeners

Agenda

Part 1: New immersive sound formats

Part 2: Unified 3D speaker layouts for multiple listeners

Part 3: Case study: Practical implementation in a real project.



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Immersive Audio: unified 3D speaker layouts for multiple listeners

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Part 1: New immersive sound formats

Part 1.1: Immersive sound innovations

Part 1.2: 3D formats

Part 1.3: Additional constraints for multiple listeners

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Part 1: New immersive sound formats

What is immersive sound?

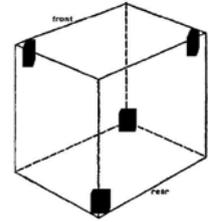
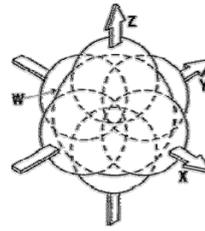


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Part 1: New immersive sound formats

Immersive sound: 3 key innovations.

1. Sound reproduction with height.
 - Real 3D soundstage with depth
 - Ambisonics (Michael Gerzon, 1978)
2. Higher speaker count
 - high spatial resolution
 - large listening area
 - Wave Field Synthesis
 - (University of Delft, 1978)
3. Object-based audio
 - Scalable audio
 - (Caruso project Europe, 2004)



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- Part 1.1: Immersive sound innovations
- Part 1.2: 3D formats
- Part 1.3: Additional constraints for multiple listeners

Part 2: Unified 3D speaker layouts for multiple listeners

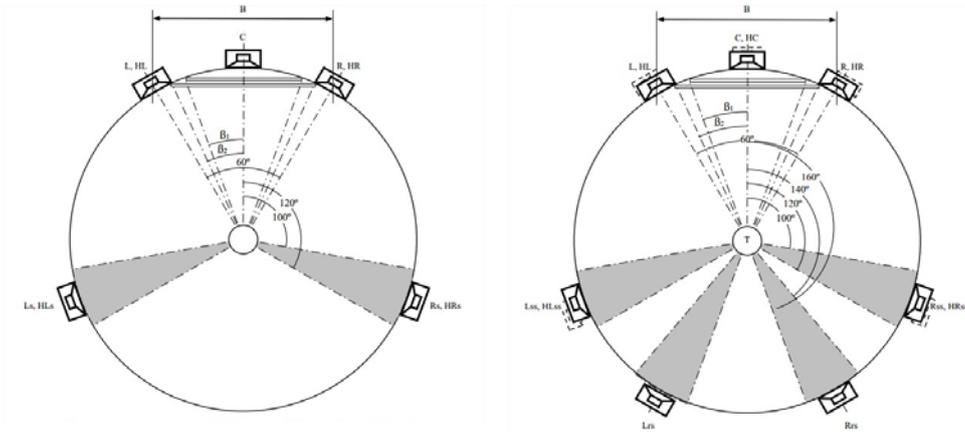
Part 3: Case study: Practical implementation in a real project.

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Part 1: New immersive sound formats

Auro3D.

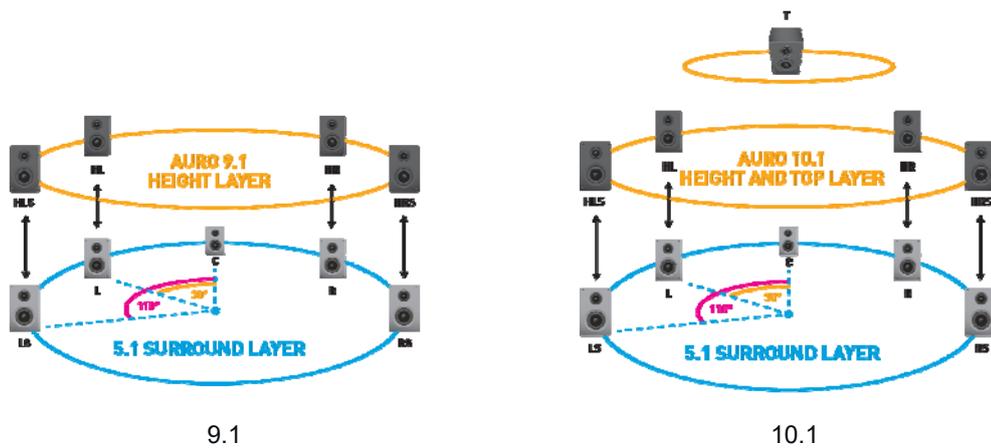


Based on existing ITU formats.



Part 1: New immersive sound formats

Auro3D.



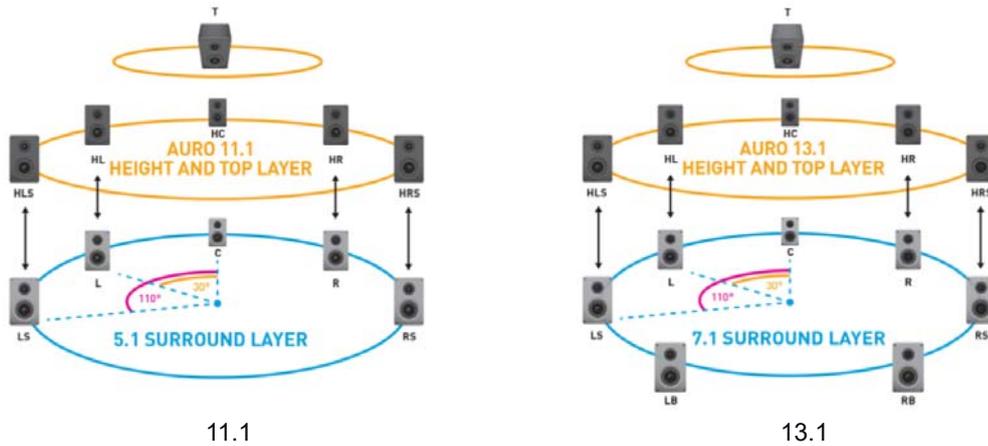
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10.1



Part 1: New immersive sound formats

Auro3D.



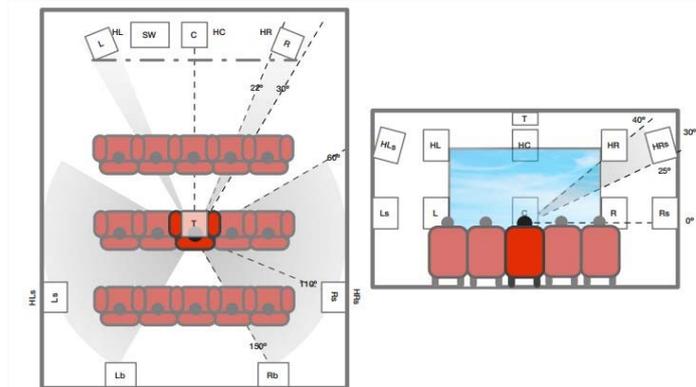
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13.1

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Part 1: New immersive sound formats

Auro3D.

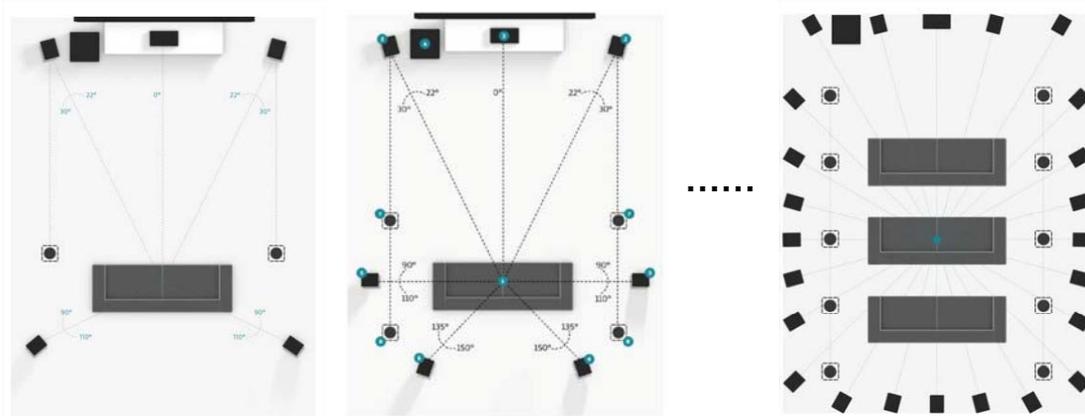


Recommended angles

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Part 1: New immersive sound formats

Dolby Atmos.

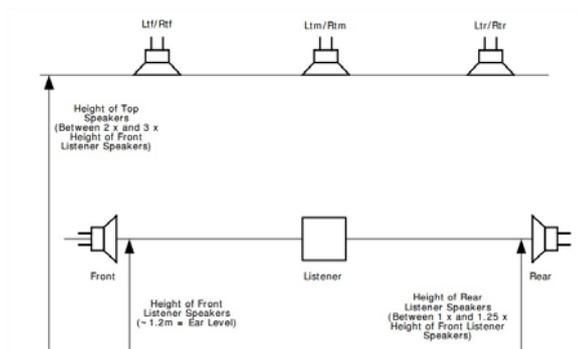
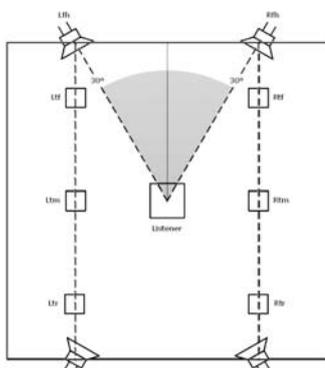


Highly scalable



Part 1: New immersive sound formats

Dolby Atmos.

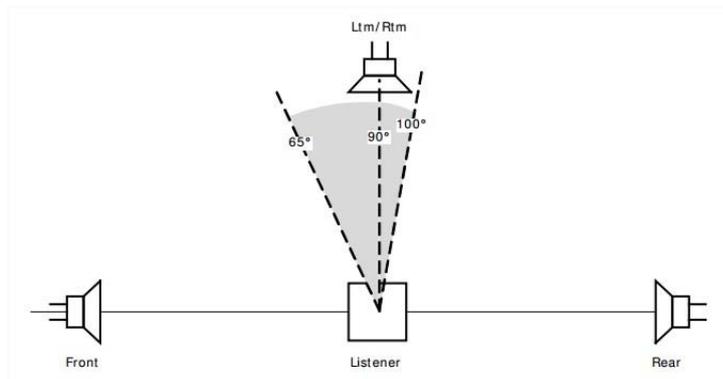


Guidelines for upper speakers alignment



Part 1: New immersive sound formats

Dolby Atmos.

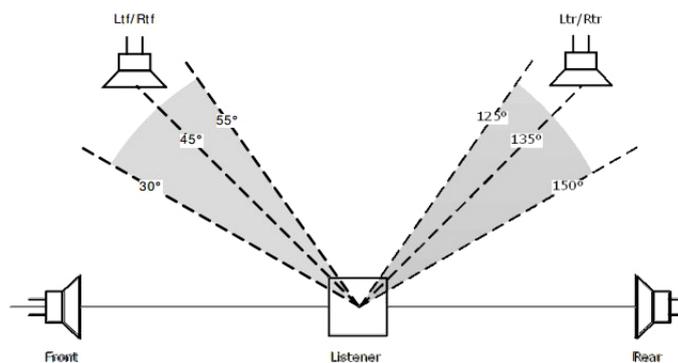


Elevation angles for 2 "top" / "overhead" speakers implementations

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Part 1: New immersive sound formats

Dolby Atmos.

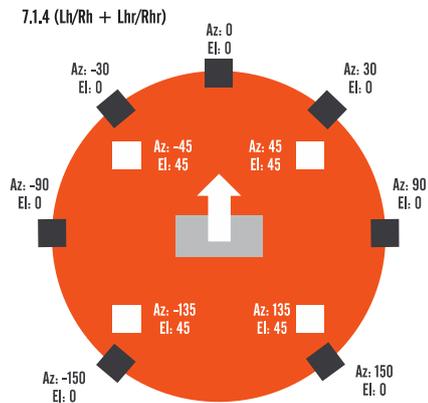


Elevation angles for 4 overhead speakers implementations

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Part 1: New immersive sound formats

DTS:X



- Initially limited to 7.1.4
- Dialog level control (for intelligibility, narration/commentaries)

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Part 1: New immersive sound formats

Additional aspects.

Immersive sound formats have been developed for:

- a wide range of content
(TV, pure music without picture, games, virtual reality)
- a wide diversity of listening contexts
(studios, high end home installations, mass market home installations, headphones, mobility...)

As a result, formats provides generic recommendations corresponding to an **idealized context** with one listener surrounded by speakers, without specific constraints such as room size, screen, multiple listeners....

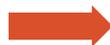
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Part 1: New immersive sound formats

Additional aspects.



From the ideal lab situation....



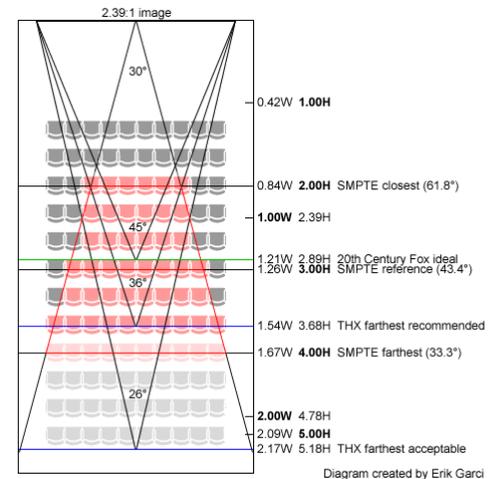
.... to the specific high end home theater situation

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Part 1: New immersive sound formats

Additional aspects: Sound-to-picture coherence

- Optimal view angle for video:
 - HDTV 1080p: $\pm 16.5^\circ$
 - UHD 4k: $\pm 30.5^\circ$
- Optimal view angle for film presentation:
 - Reference angle: $\pm 22^\circ$
 - Range: $\pm 13^\circ$ to $\pm 31^\circ$
- Sound-to-picture coherence requires L-R speakers close to the edge of the screen
- It automatically defines
 - the main listening position
 - the maximum depth of the listening area.



(Source: www.acousticfrontiers.com)

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Part 1: New immersive sound formats

Additional aspects: Visual head clearance

- Increase of screen height
 - With screens width of 4m → screen height is 2,25m (assuming 16:9 picture).
- Critical for multiple rows installations
- To avoid visual occlusion:
 - back seats should be elevated (stadium)
 - and the plane-of-view should be tilted by 10°-20°

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Part 1: New immersive sound formats

Additional aspects: Optimal room proportions

Compromise between 2 aspects:

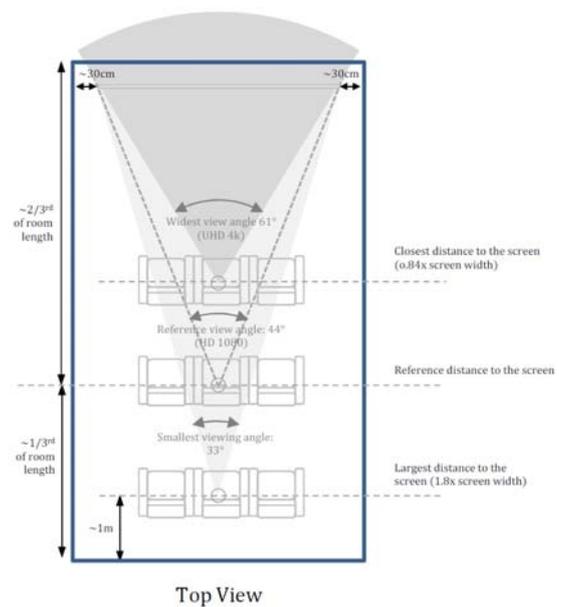
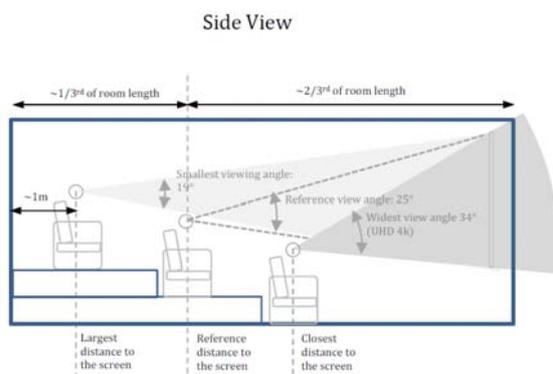
- Avoid illuminating side walls
 - Room should be wider than the screen
- Ensure compatibility between Atmos and Auro.
 - Dolby ceiling speakers should be close to the side walls
 - Room should be as wide as the screen

→ Optimal room width: 30cm (1 foot) wider than the screen.

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Part 1: New immersive sound formats

Additional aspects: Optimal room proportions



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Part 1: New immersive sound formats

Other additional aspects (not covered in this presentation)

- Loudspeaker characteristics and orientation
- Speaker electronic correction
- Acoustic treatment
- Room optimization
- Subwoofer and bass management

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Immersive Audio: unified 3D speaker layouts for multiple listeners

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Part 2.1: Screen speakers

Part 2.2: Surround speakers

Part 2.3: Front wide speakers

Part 2.4: Upper speakers

Part 3: Case study: Practical implementation in a real project.

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Part 2: Unified 3D speaker layouts for multiple listeners

Different speaker groups

- A 3D immersive audio loudspeaker system should produce **one unique 3D sound image**.
- But home theater sound supports picture on the screen:
 - It sets head position and orientation
 - and all directions are no longer equivalent
- Therefore different groups of speakers need to be **placed** according to their **function**:
 - Screen speakers
 - Surround speakers
 - Front wide speakers
 - Upper speakers
 - Subwoofers

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Part 2: Unified 3D speaker layouts for multiple listeners

Different speaker groups

- A 3D immersive audio loudspeaker system should produce one unique 3D sound image.
- But home theater sound supports picture on the screen which:
 - Sets head position and orientation
 - All directions are no longer equivalent
- Therefore different groups of speakers need to be placed according to their function:
 1. Screen speakers
 2. Surround speakers
 3. Front wide speakers
 4. Upper speakers
 5. Subwoofers



Sequence to build an
immersive sound system

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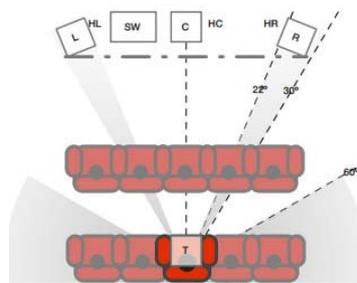
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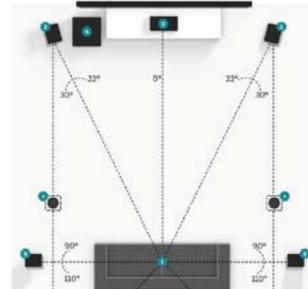
Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for screen speakers

- Angle recommendation from Dolby, Auro, DTS.



Auro3D



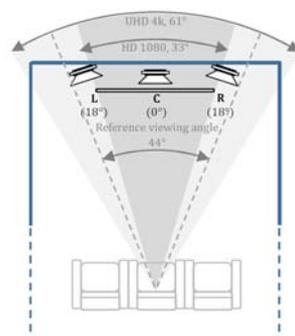
Dolby

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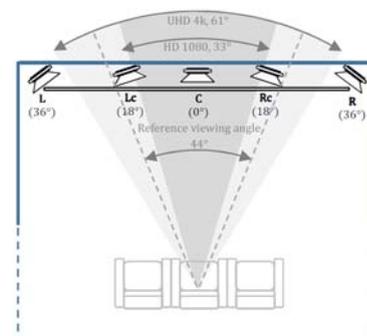
Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for screen speakers

- 3 or 5 screen speakers?
 - Narrow visual angle $< \pm 20^\circ$
 - Wide visual angle $> \pm 35^\circ$



Top View



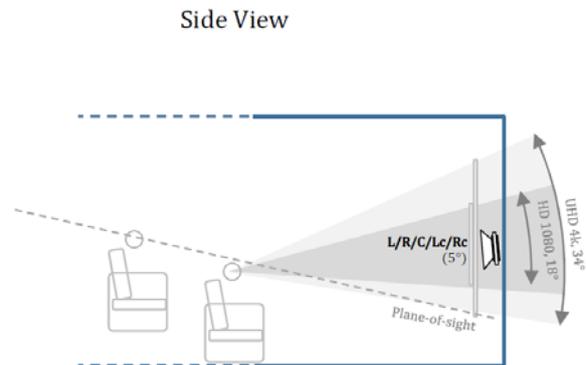
Top View

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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for screen speakers

- Vertical alignment of screen speakers
 - Centered to the screen
 - Slightly below if the screen is higher



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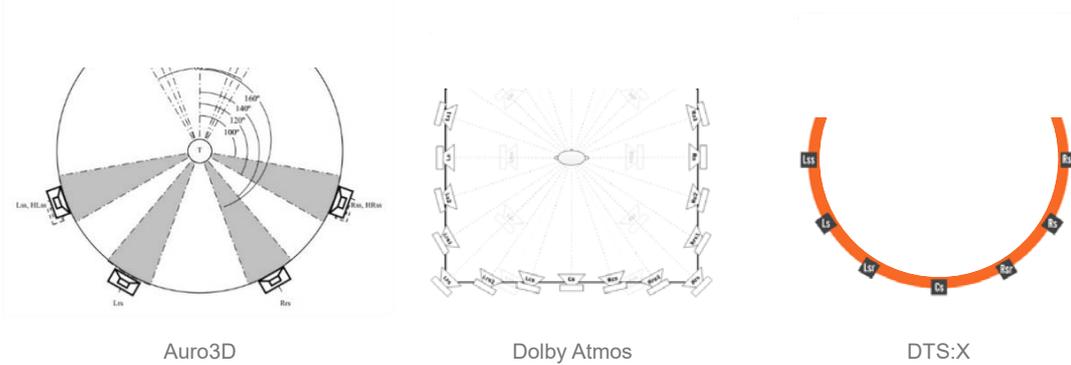
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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for surround speakers

- Guidelines for one listening position.



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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for surround speakers – **multiple listening positions**

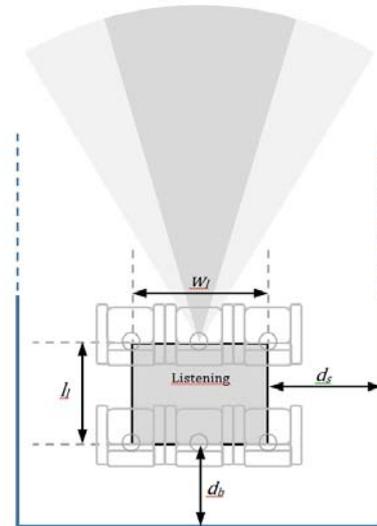
- The **number of surround** speakers is a function of:
 - The **size of the listening area**.
 - The **size of the listening area relative to the size of the room**.
 - = for a given room size, the number of speakers increases with listening area.
 - Avoid a speaker becomes dominant and pull most of the 3D soundstage

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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for surround speakers – **multiple listening positions**

- Number of surround speakers.
 - **Formula and tables**



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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for surround speakers – **multiple listening positions**

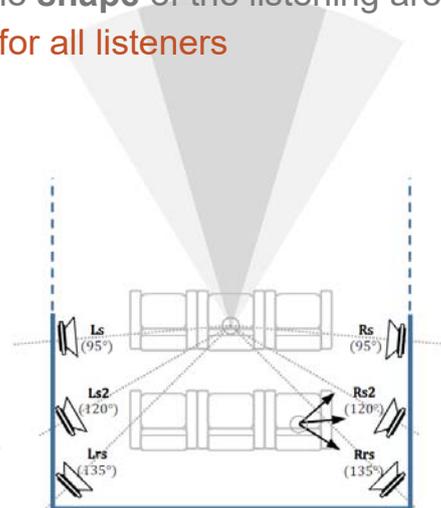
- Adapt the **type** of surround speakers to the **shape** of the listening area.
 - **Fundamental goal: same experience for all listeners**
 - Effect mixed on the side → perceived on the side for every listeners.
 - Effect mixed on the back → perceived on the back for every listeners.

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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for surround speakers – **multiple listening positions**

- Adapt the **type** of surround speakers to the **shape** of the listening area.
 - **Fundamental goal: same experience for all listeners**
 - Effect mixed on the side
→ perceived on the side for every listeners.
 - Effect mixed on the rear/back
→ perceived on the rear/back for every listeners.

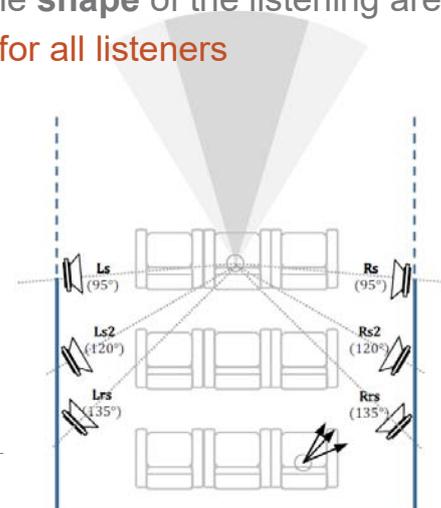


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Part 2: Unified 3D speaker layouts for multiple listeners

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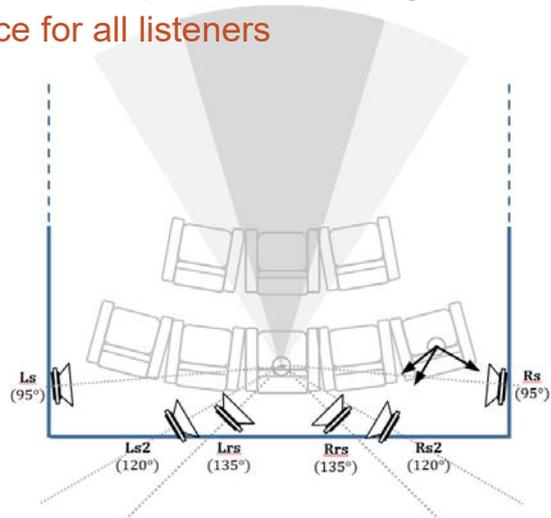
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Recommendations for surround speakers – **multiple listening positions**

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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for surround speakers – **multiple listening positions**

- Adapt the **type** of surround speakers to the **shape** of the listening area.
 - **Fundamental goal: same experience for all listeners**

- Effect mixed on the side
 - perceived on the side for every listeners.
- Effect mixed on the back
 - perceived on the back for every listeners.

- **How to achieve same experience for all listeners?**

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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for surround speakers – **multiple listening positions**

- Adapt the **type** of surround speakers to the **shape** of the listening area.
 - **Fundamental goal: same experience for all listeners**
 - Effect mixed on the side
 - perceived on the side for every listeners.
 - Effect mixed on the back
 - perceived on the back for every listeners.
 - **How to achieve same experience for all listeners?**
 - **→ With exclusion areas relative to the listening area (not the room)**

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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for surround speakers – **multiple listening positions**

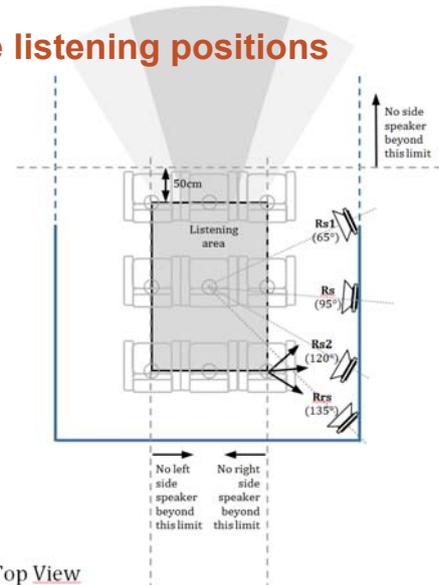
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 - Effect mixed on the side
 - perceived on the side for every listeners.
 - Effect mixed on the back
 - perceived on the back for every listeners.
 - **How to achieve same experience for all listeners?**
 - **→ With exclusion areas relative to the listening area (not the room).**
(the « listener box rule »)

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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for surround speakers – multiple listening positions

- Adapt the **type** of surround speakers to the **shape** of the listening area.
 - **Exclusion areas relative to the listening area.**
 - All **side** speakers should be on the **side** of the listening area.

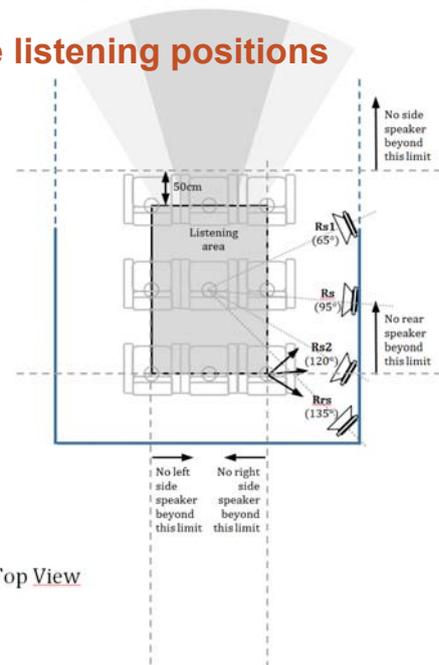


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for surround speakers – multiple listening positions

- Adapt the **type** of surround speakers to the **shape** of the listening area.
 - **Exclusion areas relative to the listening area.**
 - All **side** speakers should be on the **side** of the listening area.
 - All **rear** speakers should be at the **rear** of the listening area

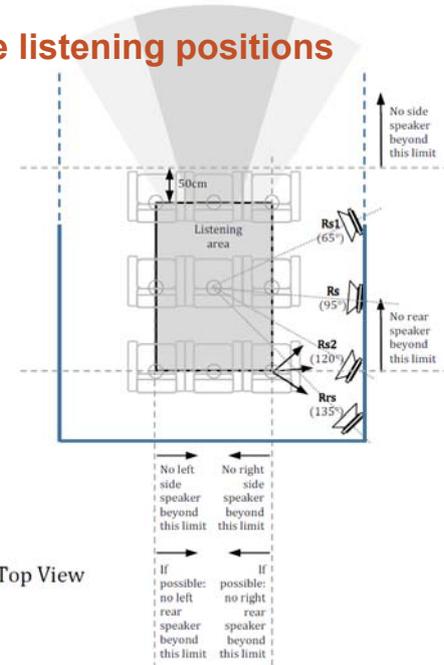


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for surround speakers – multiple listening positions

- Adapt the **type** of surround speakers to the **shape** of the listening area.
 - **Exclusion areas relative to the listening area.**
 - All **side** speakers should be on the **side** of the listening area.
 - All **rear** speakers should be at the **rear** of the listening area
 - If possible, all **rear left** speakers should be heard at the **left** of the listening area. Same for **rear right**.

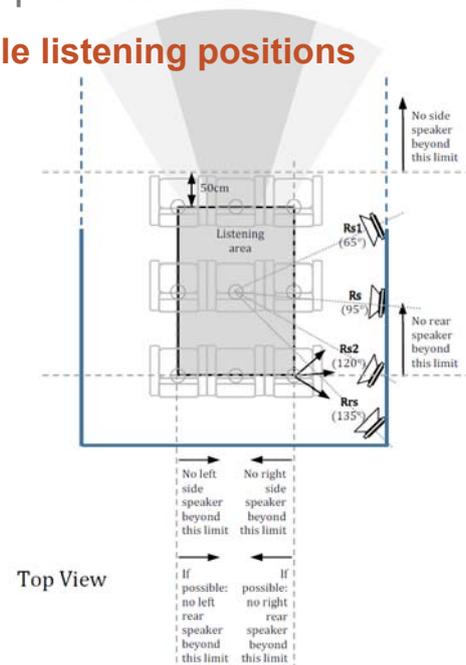


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Recommendations for surround speakers – multiple listening positions

- Adapt the **type** of surround speakers to the **shape** of the listening area.
 - **Exclusion areas relative to the listening area.**
 - All **side** speakers should be on the **side** of the listening area.
 - All **rear** speakers should be at the **rear** of the listening area
 - If possible, all **rear left** speakers should be heard at the **left** of the listening area. Same for **rear right**.
 - All **back** speakers should be at the **back** of the listening area

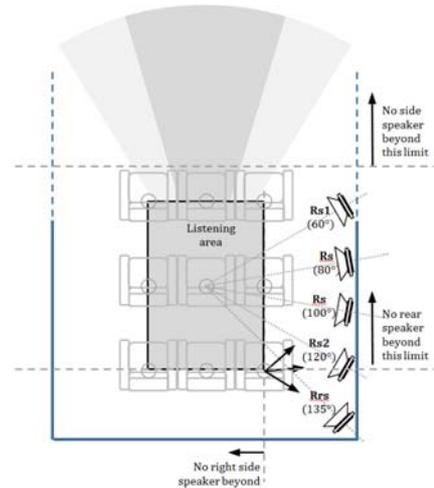


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for surround speakers – **multiple listening positions**

- Adapt the **type** of surround speakers to the **shape** of the listening area.
 - For long listening areas:**
 - **array the side speakers.**
 - **constant power array (-3dB)**

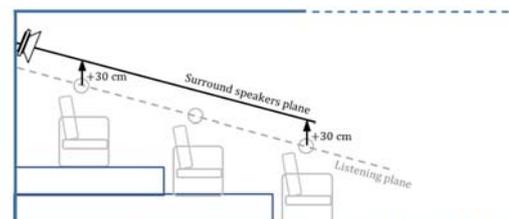


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for surround speakers – **multiple listening positions**

- Vertical head clearance.
 - Speaker occlusion/shadowing dramatically corrupts tonal balance and localization.
 - Surround speakers are elevated 30cm above the listening plane
(instead of 60cm for 7.1 to avoid above-the-head presentation)

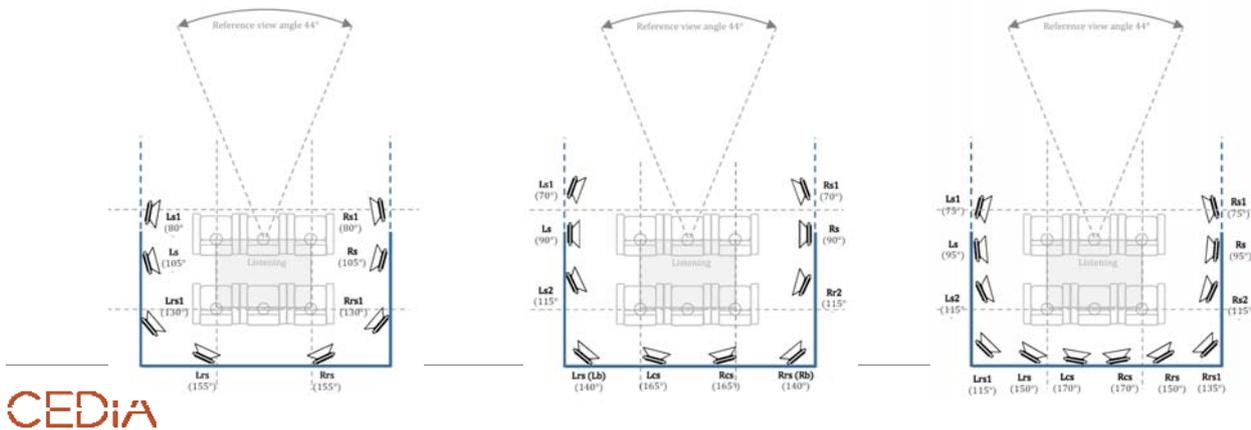


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for surround speakers – **multiple listening positions**

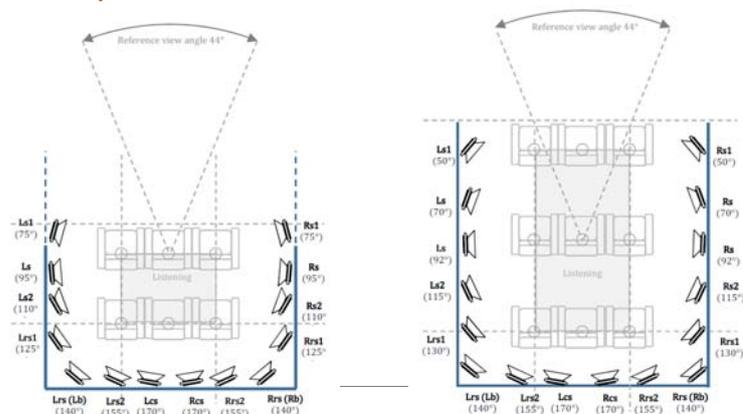
- Recommended layouts.
 - 8, 10 and 12 ear-level surround speakers.



Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for surround speakers – **multiple listening positions**

- Recommended layouts.
 - 14 and 16 ear-level surround speakers.



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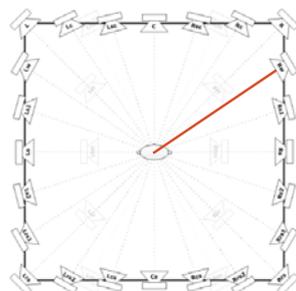
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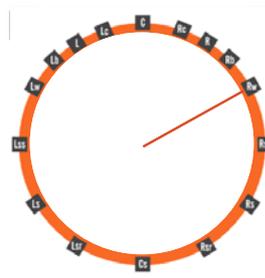
Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for front-wide speakers

- Guidelines for one listening position.
 - $\pm 60^\circ$ relative to the center.



Dolby Atmos



DTS:X

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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for front-wide speakers – **multiple listening positions**

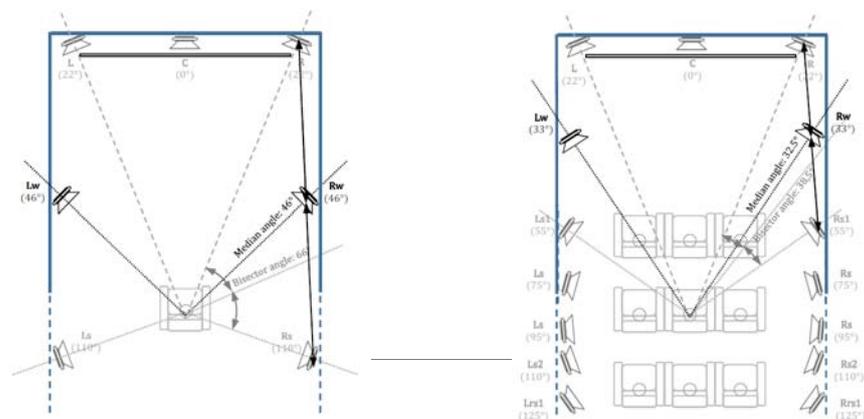
- Why front wide speaker placement in high end home theater.
 - Fill the hole between screen speakers and surround speakers...
 - ... regardless of the screen and the listening area
 - Human localization is not very good for front-side directions
 - How to fill the hole?
 - One simple method.
 - The *median angle* is preferred over the *bisector angle*

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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for front-wide speakers – **multiple listening positions**

- Recommended layouts.
 - Normal L/R angle (reference view angle of $\pm 22^\circ$)

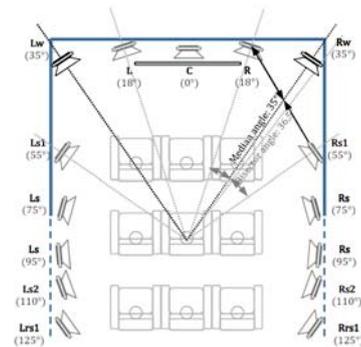
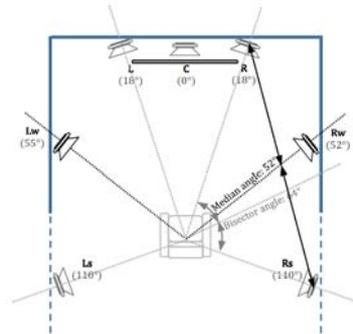


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for front-wide speakers – **multiple listening positions**

- Recommended layouts.
 - Narrow L/R angle

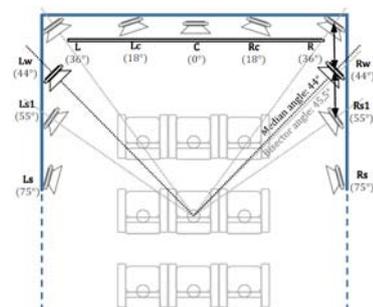
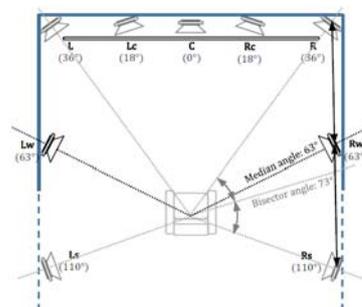


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for front-wide speakers – **multiple listening positions**

- Recommended layouts.
 - Wide L/R angle



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Immersive Audio: unified 3D speaker layouts for multiple listeners

Agenda

Part 1: New immersive sound formats

Part 2: Unified 3D speaker layouts for multiple listeners

Part 2.1: Screen speakers

Part 2.2: Surround speakers

Part 2.3: Front wide speakers

Part 2.4: Upper speakers

Part 3: Case study: Practical implementation in a real project.

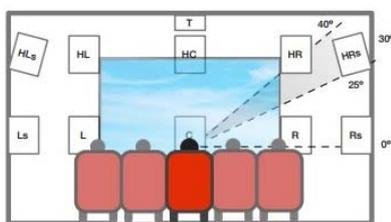
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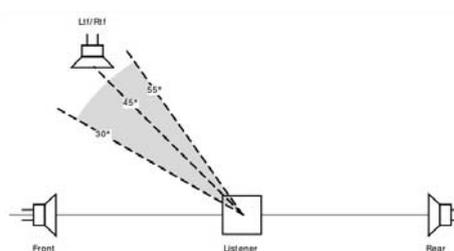
Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers

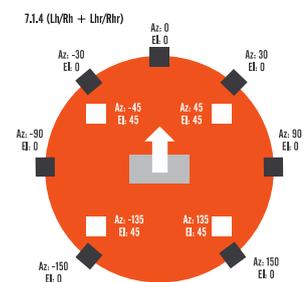
- Guidelines for one listening position.



Auro3D



Dolby Atmos



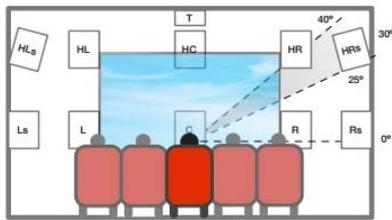
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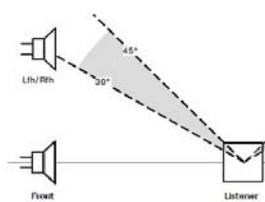
Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers

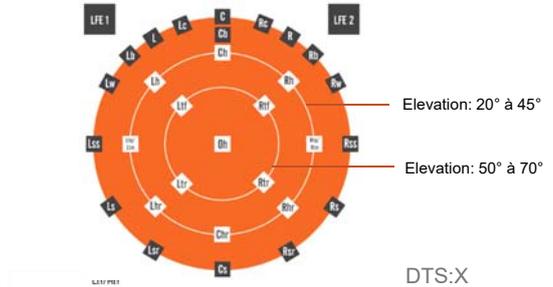
- Guidelines for one listening position.
 - 2 upper layers: *height and top*.



Auro3D



Dolby Atmos



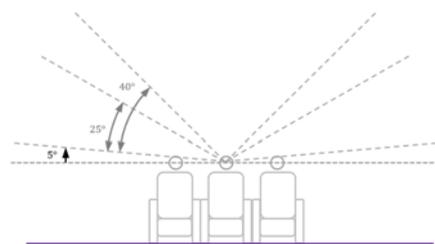
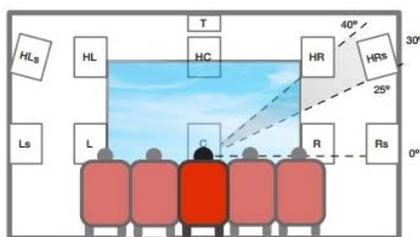
DTS:X

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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – multiple listening positions

- Guidelines for one listening position.
 - Height speakers: *wall mount or ceiling mount*

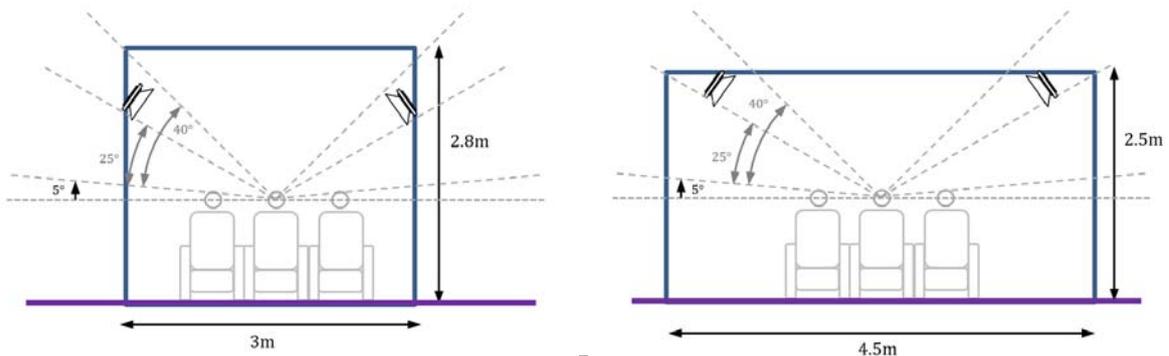


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers

- Guidelines for one listening position.
 - Height speakers: *wall mount or ceiling mount*



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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – **multiple listening positions**

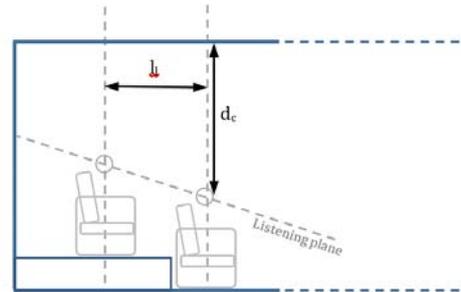
- The **number** of upper speakers is a function of:
 - The length of the listening area.
 - The length of the listening area relative to the height of the ceiling.
 - = for a given room length, the number of speakers increases when the ceiling height is reducing.
 - Avoid a speaker becomes dominant and pull most of the 3D soundstage

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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – **multiple listening positions**

- Adapt the **number** of upper speakers to the **length** of the listening area.
 - **Formula and tables**



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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – **multiple listening positions**

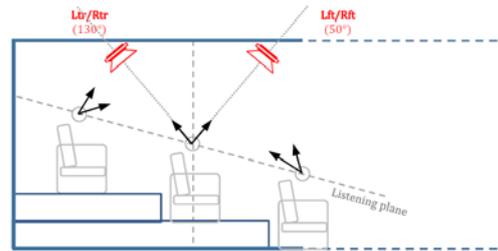
- Adapt the **position** of upper speakers to the **shape** of the listening area.
 - **Fundamental goal: same experience for all listeners**
 - Effect mixed on the front height
 - perceived on the front height for every listeners.
 - Effect mixed on the back height
 - perceived on the back height for every listeners.

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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – **multiple listening positions**

- Adapt the **position** of upper speakers to the **shape** of the listening area.
 - Fundamental goal: same experience for all listeners**
 - Effect mixed on the front height
 - perceived on the front height for every listeners.
 - Effect mixed on the back height
 - perceived on the back height for every listeners.

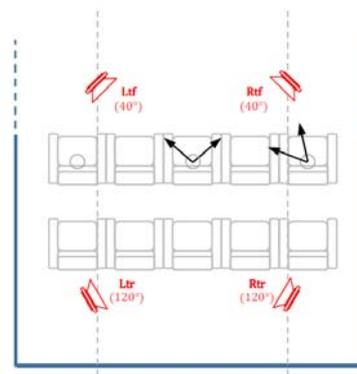


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – **multiple listening positions**

- Adapt the **position** of upper speakers to the **shape** of the listening area.
 - Fundamental goal: same experience for all listeners**
 - Effect mixed on the right height
 - perceived on the right height for every listeners.
 - Effect mixed on the left height
 - perceived on the left height for every listeners.



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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – **multiple listening positions**

- Adapt the **position** of upper speakers to the **shape** of the listening area.
 - **Fundamental goal: same experience for all listeners**
 - Effect mixed on the left (or right) side
→ perceived on the left (or right) side
for every listeners.
 - Effect mixed on the front (or back)
→ perceived on the front (or back)
for every listeners.
 - **How to achieve same experience for all listeners?**

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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – **multiple listening positions**

- Adapt the **position** of upper speakers to the **shape** of the listening area.
 - **Fundamental goal: same experience for all listeners**
 - Effect mixed on the left (or right) side
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 - Effect mixed on the front (or back)
→ perceived on the front (or back)
for every listeners.
 - **How to achieve same experience for all listeners?**
→ **With exclusion areas relative to the listening area (not the room).**

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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – **multiple listening positions**

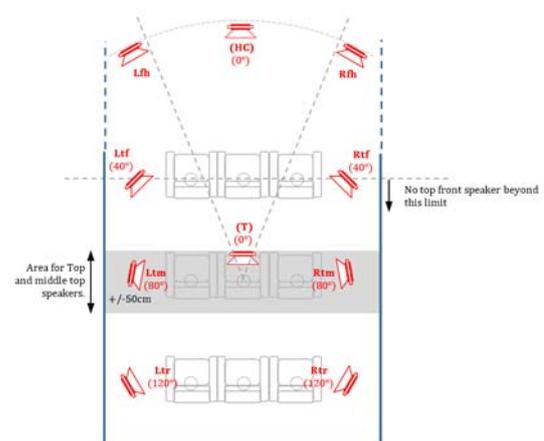
- Adapt the **position** of upper speakers to the **shape** of the listening area.
 - **Fundamental goal: same experience for all listeners**
 - Effect mixed on the left (or right) side
→ perceived on the left (or right) side for every listeners.
 - Effect mixed on the front (or back)
→ perceived on the front (or back) for every listeners.
 - **How to achieve same experience for all listeners?**
→ **With exclusion areas relative to the listening area (not the room).**
(the « listener box rule »)

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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – **multiple listening positions**

- Adapt the **position** of upper speakers to the **shape** of the listening area.
 - → **Exclusion areas relative to the listening area.**
 - All upper **front** speakers should be at the **front** of the listening area.

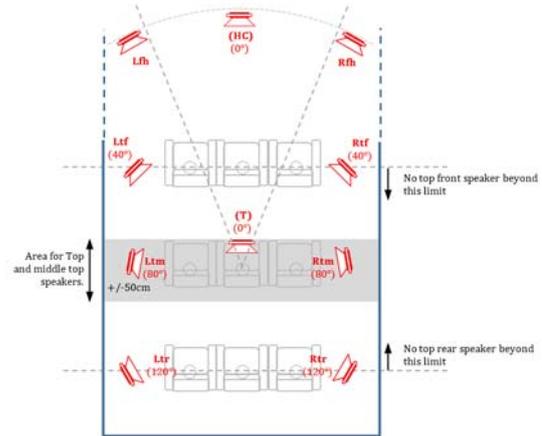


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – multiple listening positions

- Adapt the **position** of upper speakers to the **shape** of the listening area.
 - **Exclusion areas relative to the listening area.**
 - All upper **front** speakers should be at the **front** of the listening area.
 - All upper **rear** speakers should be at the **rear** of the listening area.

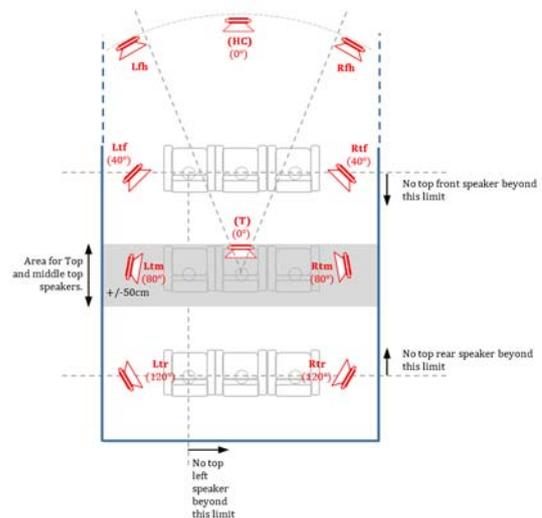


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – multiple listening positions

- Adapt the **position** of upper speakers to the **shape** of the listening area.
 - **Exclusion areas relative to the listening area.**
 - All upper **front** speakers should be at the **front** of the listening area.
 - All upper **rear** speakers should be at the **rear** of the listening area.
 - All upper **left** speakers should be at the **left** of the listening area.

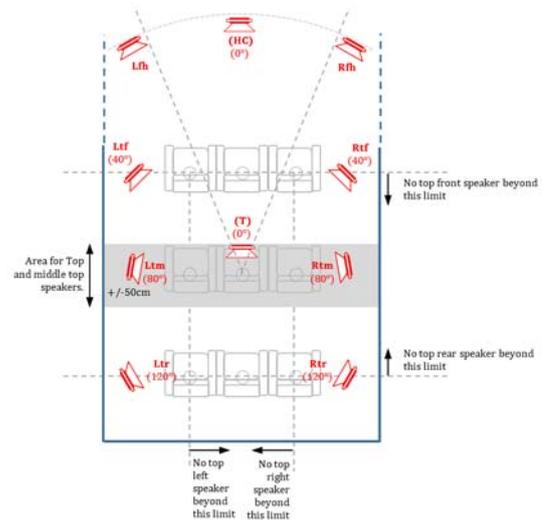


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – multiple listening positions

- Adapt the **position** of upper speakers to the **shape** of the listening area.
 - **Exclusion areas relative to the listening area.**
 - All upper **front** speakers should be at the **front** of the listening area.
 - All upper **rear** speakers should be at the **rear** of the listening area.
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 - All upper **right** speakers should be at the **right** of the listening area.

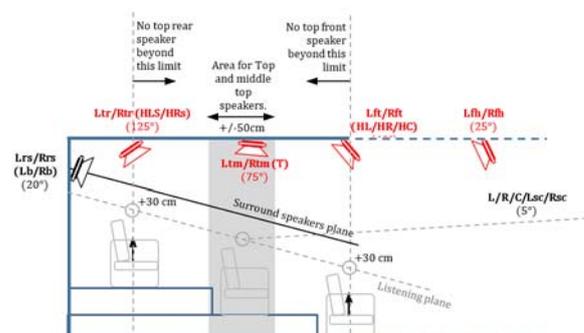


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – multiple listening positions

- Adapt the **position** of upper speakers to the **shape** of the listening area.
 - **Exclusion areas relative to the listening area.**
 - All upper **front** speakers should be at the **front** of the listening area.
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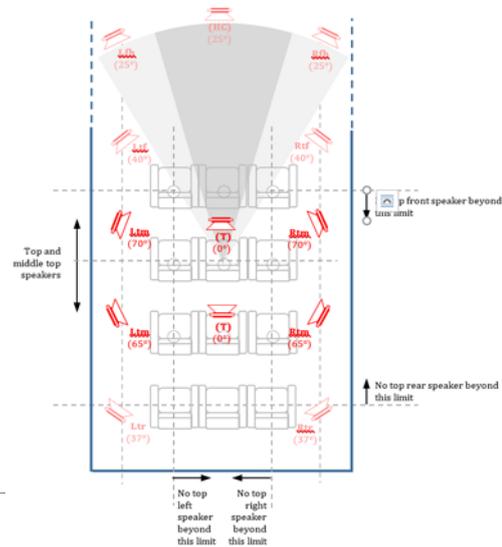


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – **multiple listening positions**

- Adapt the **position** of surround speakers to the **shape** of the listening area.
 - For long listening areas:
 - array the top speakers.
 - constant power array (-3dB)

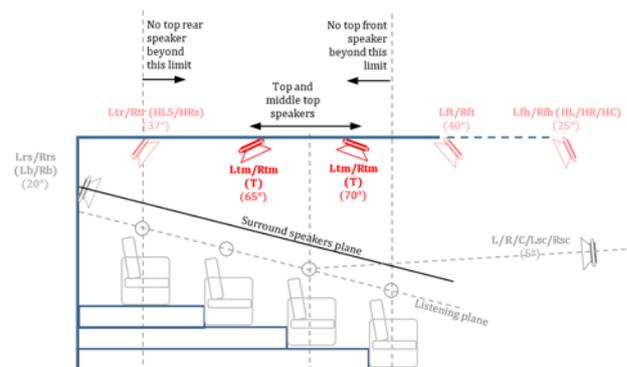


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – **multiple listening positions**

- Adapt the **position** of surround speakers to the **shape** of the listening area.
 - For long listening areas:
 - array the top speakers.
 - constant power array (-3dB)

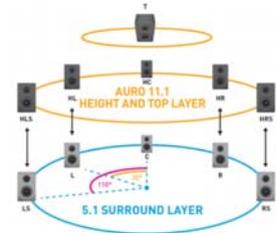


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – **multiple listening positions**

- Achieve consistency between ear-level and upper-layer.
 - Requirement for Auro3D: 2 identical layers on top of each other (up to 11.1)
 - But beyond 11.1 there are more ear-level speakers than upper speakers. Direct correspondence is not possible.
- The consistency between speaker layers is achieved within groups of speakers which should cover the same horizontal aperture

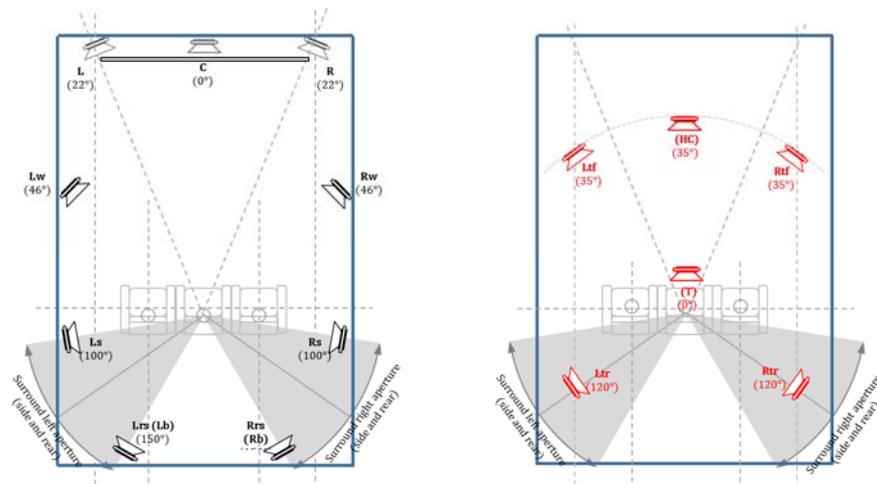


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – **multiple listening positions**

- Achieve consistency between ear-level and upper-layer.

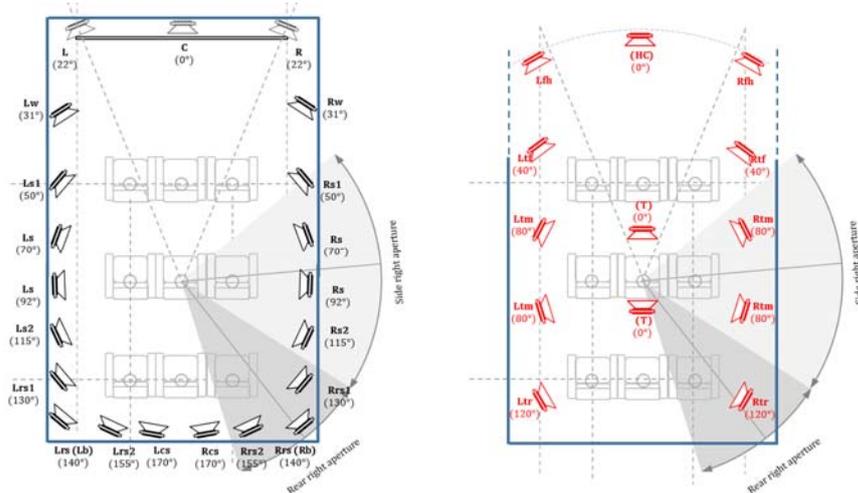


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – multiple listening positions

- Achieve consistency between ear-level and upper-layer.

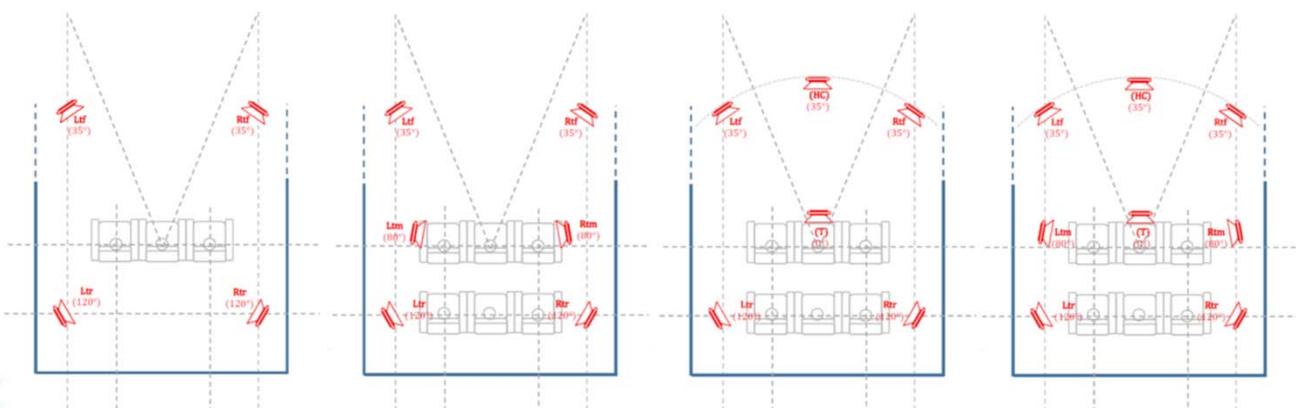


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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – multiple listening positions

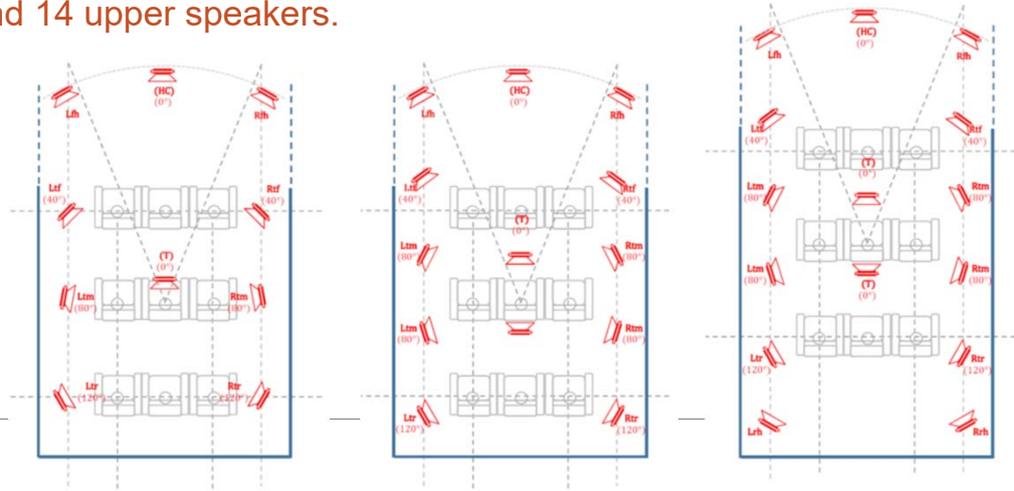
- Recommended layouts.
 - 4, 6 and 8 upper speakers.



Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for upper speakers – **multiple listening positions**

- Recommended layouts.
 - 10, 12 and 14 upper speakers.



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Immersive Audio: unified 3D speaker layouts for multiple listeners

Agenda

- Part 1: New immersive sound formats
- Part 2: Unified 3D speaker layouts for multiple listeners
- Part 3: Case study: Practical implementation in a real project.



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Sawan Nichani



- Music Producer and Recording Engineer for 10 years
- Founder of MACBEE, New Delhi, India:
 - High End custom integration.
 - Home Cinema design and engineering.
 - 4 High End Immersive sound home theater projects
(7.4.4 – 9.4.4 – 11.4.9 – 21.1.10 (with 6 subwoofers))
 - Immersive sound test lab (any layout up to 32 speakers)
- CEDIA awards:
 - 2015: Best Home Cinema Over £100,000
 - 2016: Finalist for Best Home Cinema (£50,000 to 100,000 category)
- CEDIA Board of Directors (2016)

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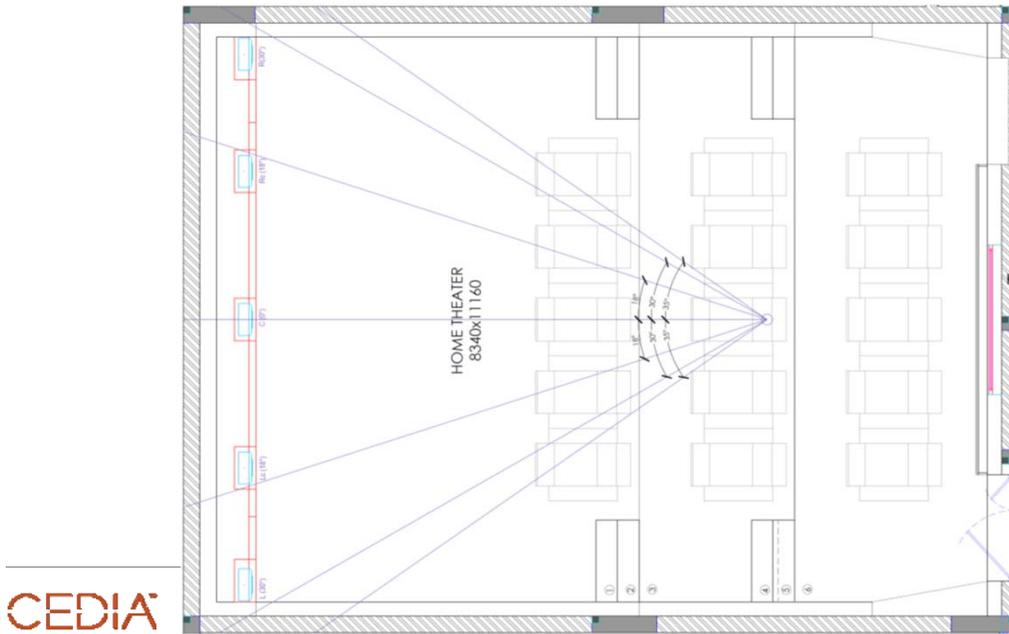
Part 3: Case study: Practical implementation in a real project.



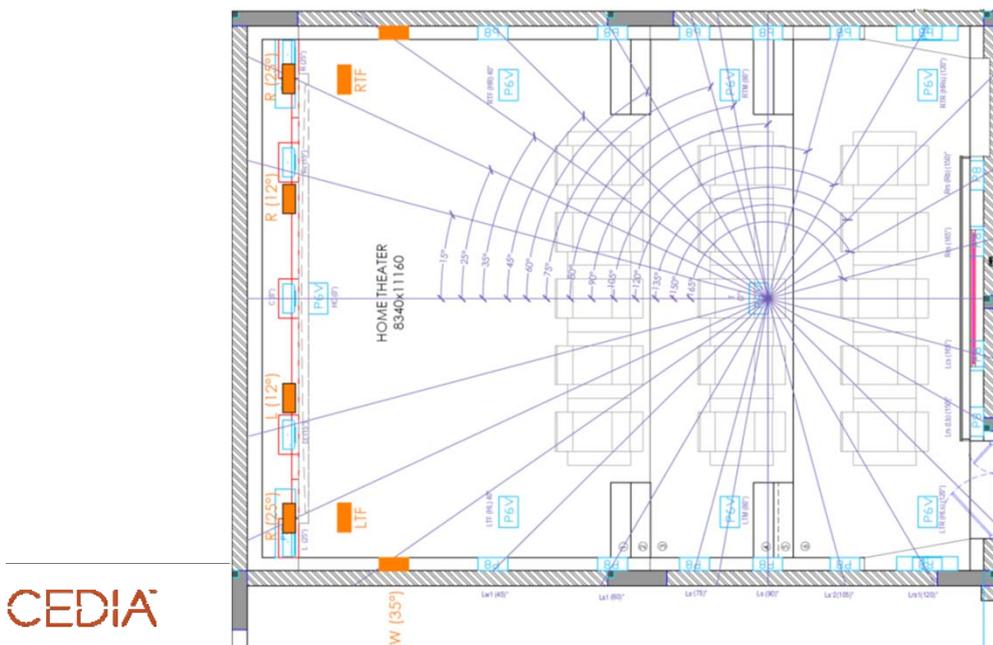
AMBISONIC CINEMA



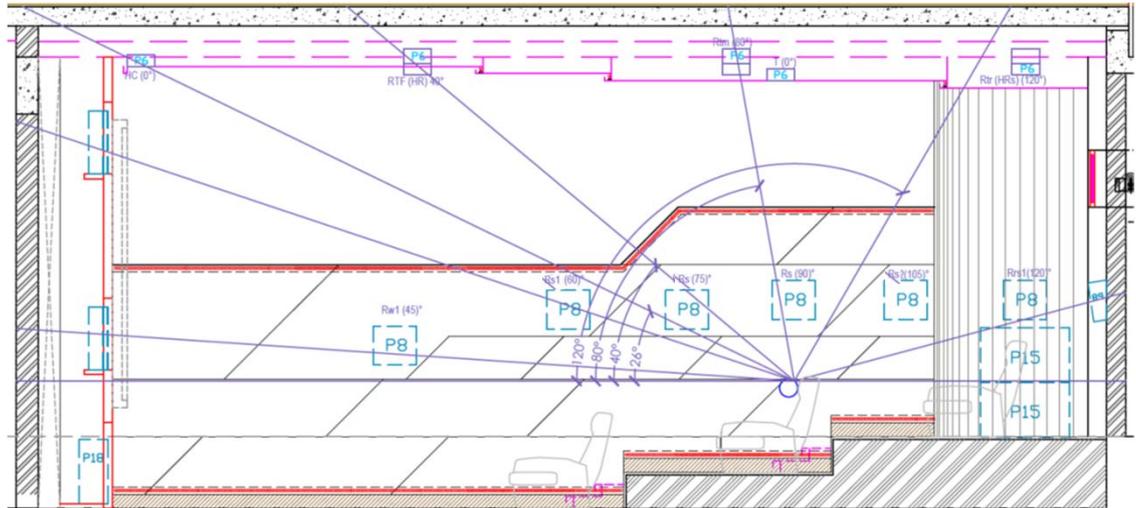
Part 3: Case study: Practical implementation in a real project.



Part 3: Case study: Practical implementation in a real project.

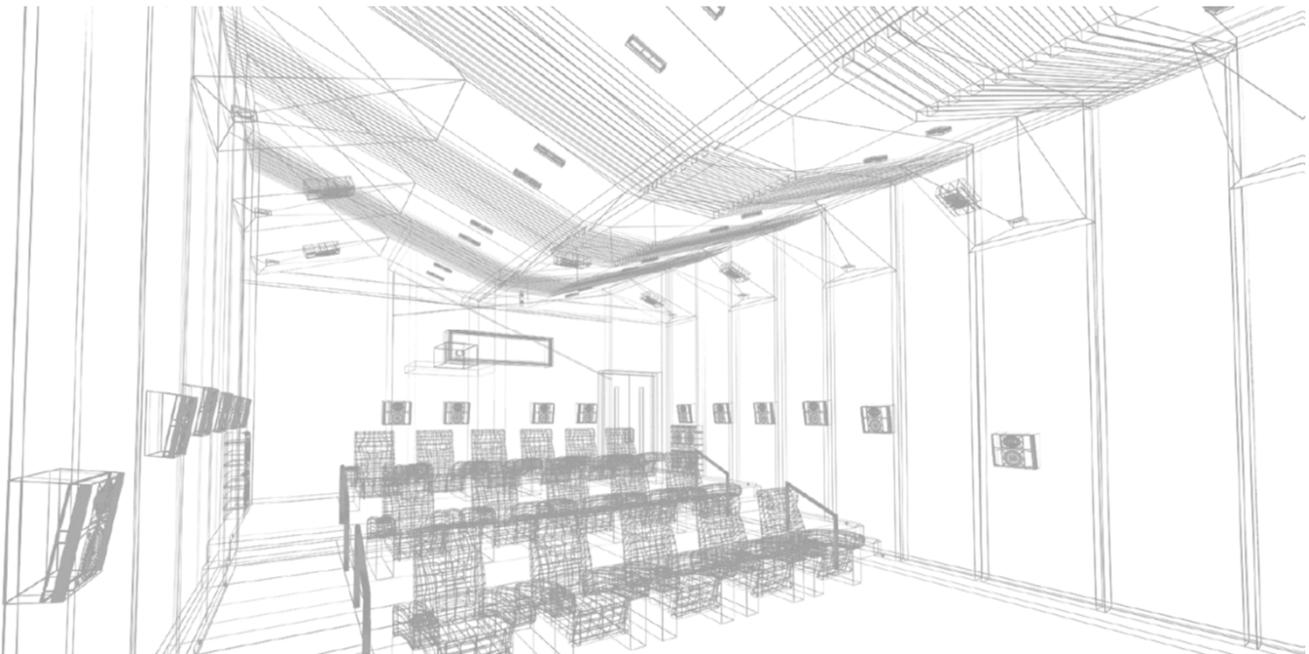


Part 3: Case study: Practical implementation in a real project.

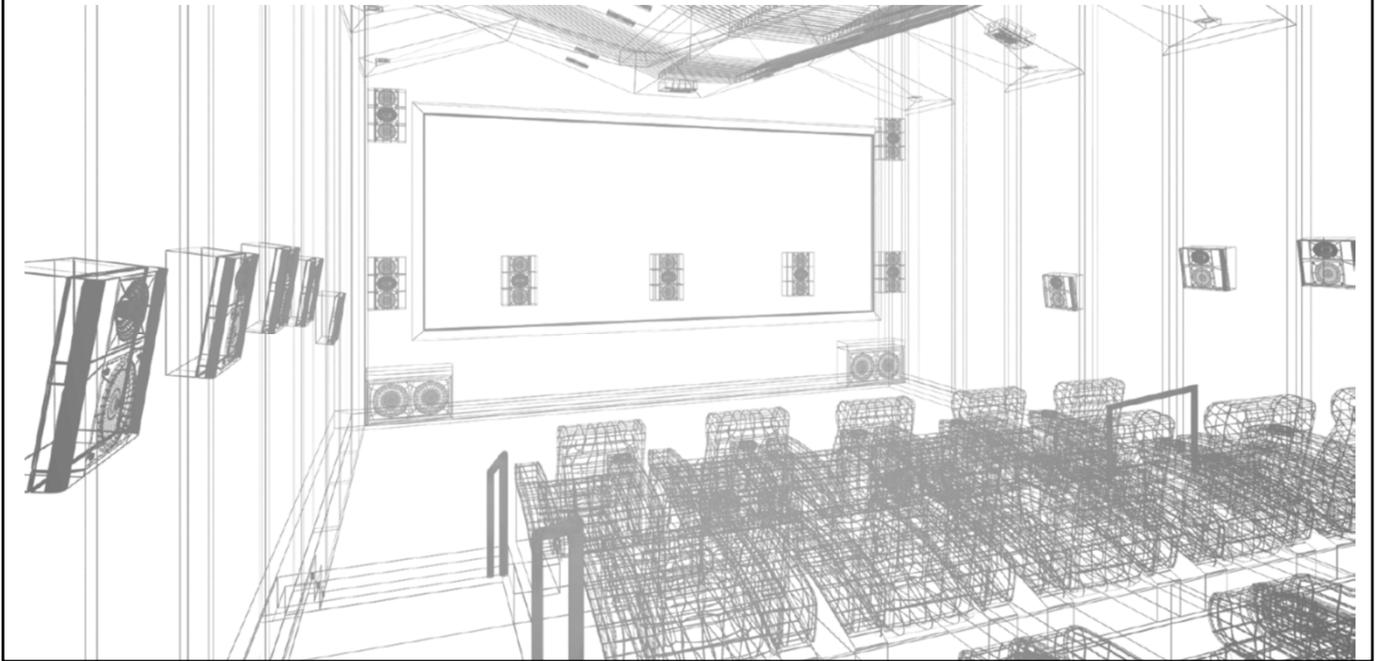


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Part 3: Case study: Practical implementation in a real project.



Part 3: Case study: Practical implementation in a real project.



Immersive Audio: unified 3D speaker layouts for multiple listeners

Agenda

Part 1: New immersive sound formats

Part 2: Unified 3D speaker layouts for multiple listeners

Part 3: Case study: Practical implementation in a real project.

CONCLUSION

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Part 2: Unified 3D speaker layouts for multiple listeners

Recommendations for wide speakers – **multiple listening positions**

- Guidelines to achieve consistent listening experience for multiple listeners.
- Rely on intuition and common sense:
 - Distribution of surround speakers.
 - Distribution of upper speakers.
 - Wide L/R angle.
- Achieve wise/creative compromises during practical implementation

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Conclusion

- Immersive audio formats and 3D speaker layouts
- Additional constraints for multiple listeners
- Building 3D speaker layouts for multiple listeners
- Apply guidelines in a practical use case.

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Questions? Thank You!

Please submit course evaluations

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