



**One audio 3D Speaker setup for all:
A solution for Auro-3D, Dolby Atmos and DTS:X**

One-for-all-Setup-Guide Version 5.0

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Holger Baier

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One audio 3D Speaker setup for all: A solution for Auro-3D, Dolby Atmos and DTS:X

A short introduction by *Holger Baier*

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1. Introduction

For all home cinema enthusiasts who like to experiment, I would like to present here a loudspeaker setup that is intended as a solution for the Height layer that can play back all currently available audio 3D formats ; Auro-3D, Dolby Atmos and DTS:X (Pro).

This loudspeaker setup can be used with all currently available audio 3D formats since it is within the specs of each of those 3D audio format.

Based on the availability of less movie content in Auro-3D versus Dolby Atmos, there might be some arguments against a loudspeaker setup that supports playback of Auro-3D only.

Link: [Overview Auro-3D titles - Movie](#)

Link: [Overview Auro-3D titles - Music](#)

However, there is much to say when comparing the Auro-3D movies versus Dolby Atmos. Patrick Schappert (www.grobi.tv) did many research and got feedback from many clients that the sounds coming from above in an Atmos movie are very limited. This is completely different with Auro-3D that is based on a different approach ; Auro-3D is delivering a "vertical coherent sound field" (see further) that allows a much more natural use of elevated sounds (like in nature where most source sounds and reflections are located between ear-level and about 30° elevation, exactly where Auro-3D's vertical stereo field is defined).

Additionally, Auro-3D has the most advanced and very powerful upmixer called "Auro-Matic®" which, in addition to "DTS Neural:X", can be used excellently for the playback of conventionally stereo or surround formats over a 3D audio speaker setup. The additional height information is then calculated from the existing signals of the channels using certain algorithms and distributed to the supported height loudspeakers. The overall immersive sound experience is often better and more natural compared to native sound mixes of object based formats. The result is, as usual, very dependent on one's own hearing sensation.

The great advantage of the Auro-Matic® over Neural:X, however, is its ability to influence and adjust upmixing in 16 stages and by selecting up to five different room sizes (Small, Medium, Large, Language, Movie).

For me personally this possibility is already a big incentive to continue using Auro-3D or the Auro-Matic, because I use the upmixer very often. Especially if the native track doesn't offer the desired or expected effects in the heights layer, the Auro-Matic can still provide some surprising effects. Whether you like it or not is a matter of taste, as mentioned above; I like it very much.

2. Auro-3D's "vertical coherent sound field all around the listener"

All Auro-3D speaker layouts up to Auro 26.1 as designed by its inventor Wilfried Van Baelen, are based on a "vertical coherent sound field all around the listener". Hundreds of tests were done by him in 2005 to understand better how the 'coherence' in the vertical axis works for our brain totally different compared to the horizontal axis. This has to do with the fact that our hearing system is horizontally oriented (we are very sensitive for time differences between left and right ear). We don't have an ear on the top of our head to capture the vertical time differences. As such, our brain is less sensitive for sounds coming from above and additionally, most important sound sources and its 3D reflections are not located there.

The result of Wilfried's research was put in a picture that has been discussed in the workshop "Surround Sound with Height (chaired by Kimio Hamasaki, inventor of the 22.2 NHK format) at the AES convention in Paris and San Francisco in 2006 and also in other conventions like *Tonmeister Tagung* in 2008 (Leipzig Germany).

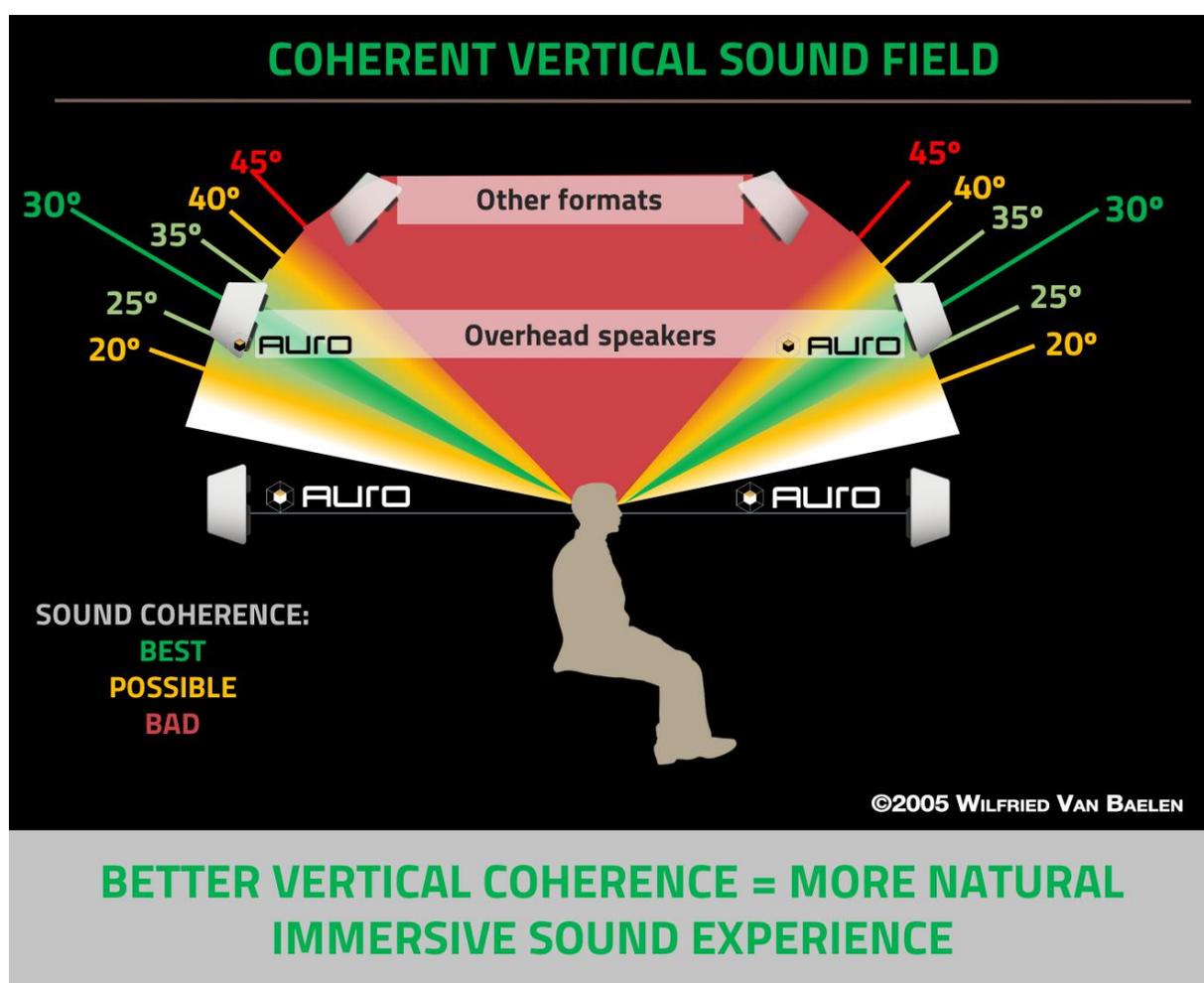


Figure 1 – Coherent vertical sound field

If the angle of two speakers located above each other is too big, it loses its vertical coherence which means that the sound coming from the two speakers are perceived as two different sources, even if there is a natural coherence in the source material (like ambiences etc..).

3. How does the vertical coherence differ from the horizontal coherence?

Sitting in the sweet-spot of a typical horizontal stereo speaker setup in a 60° angle, sounds can be experienced as if they can travel from left to right or coming from a location where no speaker is installed. This is called 'phantom image'. Now our hearing system is horizontally oriented. Humans are very sensitive for time differences between left and right ear. Wilfried mentioned in his lecture that the speed from a pulse on our ears going to the cortex in our brain (where the left and right ear information comes together) takes only 4 to 5 micro seconds (millionth of a second). He said that is the same wave length as 200 up to 250kHz sample. As such human beings can experience time differences (spatial information) up to 200kHz and this seems to be almost the same for young and old people.

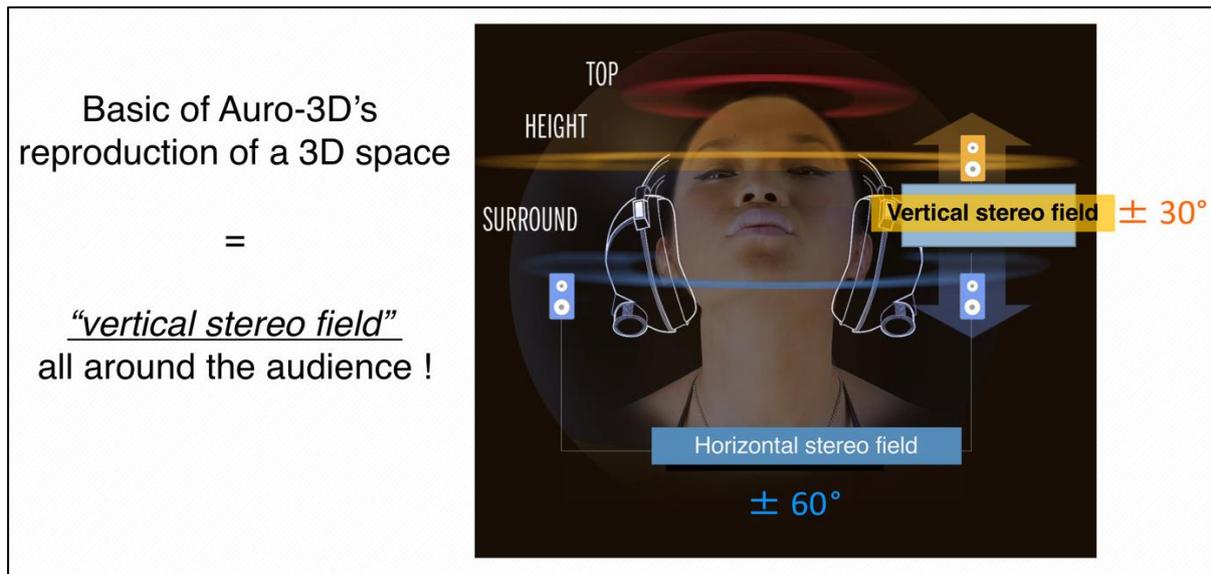


Figure 2 – Creation of vertical stereo field

Wilfried's research resulted for him into a better understanding of the coherence in the vertical axis and how such coherence can be achieved like a "vertical stereo field". The results were the basic of all his speaker layouts that create in the most efficient way the most natural immersive sound. More speakers doesn't mean that the sound is more natural, the opposite is rather true because more speakers means also more potential comb filtering which results in a lesser reproduction of the sound timbre (color) which is still the most dominant factor in sound quality tests.

"Even with a million speakers around our head, we will not be able to experience natural sound. The art is to create that natural immersive sound illusion as efficient as possible and this is the basic thought behind my concept of the Auro-3D format and its technology".

(quoted by Wilfried Van Baelen during the "Surround with Height" workshop, AES Paris & San Francisco in 2006)

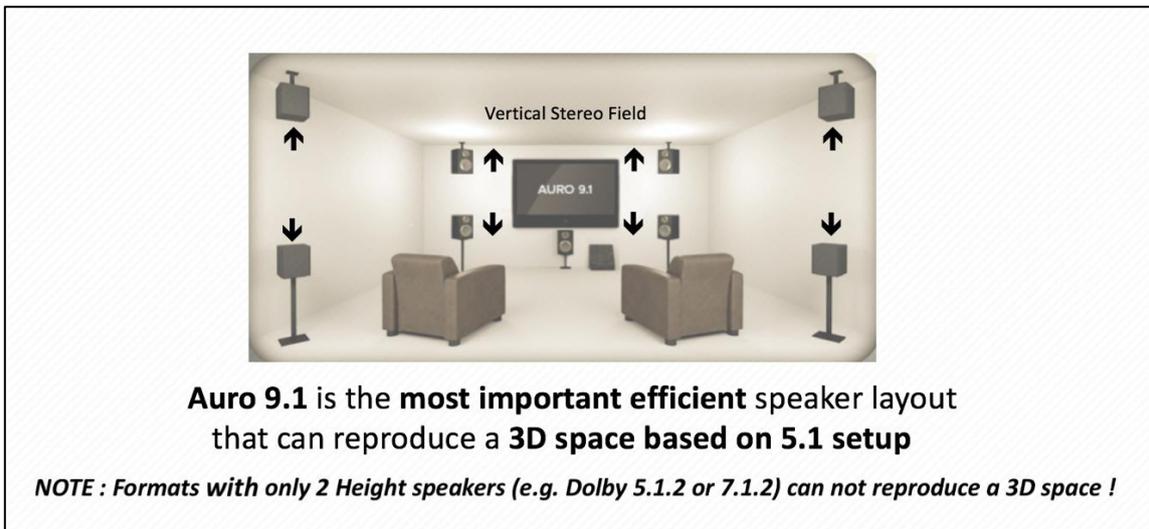


Figure 3 – Auro 9.1 speaker layout

4. THREE-layered AURO-3D versus TWO-layered Dolby ATMOS speaker layouts?

Although Wilfried Van Baelen inspired many others with his Auro-3D speaker layouts that he presented already at the AES conventions in 2006 (Paris and San Francisco), other players on the market came later unfortunately with other speaker layout proposals leading to a non-compatibility between the different systems. Dolby Atmos came with a 2 layered system (while Auro-3D is based on a 3 layered system) with the speakers placed by Dolby overhead (almost directly above your head). As such this speaker placement of Dolby creates a bad coherence in the vertical axis which means that even if the sound sources are recorded in a coherent natural sound field (like ambiences), it will be perceived as two different sources and not as the natural coherence we are used to experience in nature.

Most efficient way to split the vertical axis following Wilfried's research is using 3 layers. It can be although achieved with 2 layers in small rooms in which the 3rd layer can be generated as a phantom source of Auro's quadraphonic height layer.

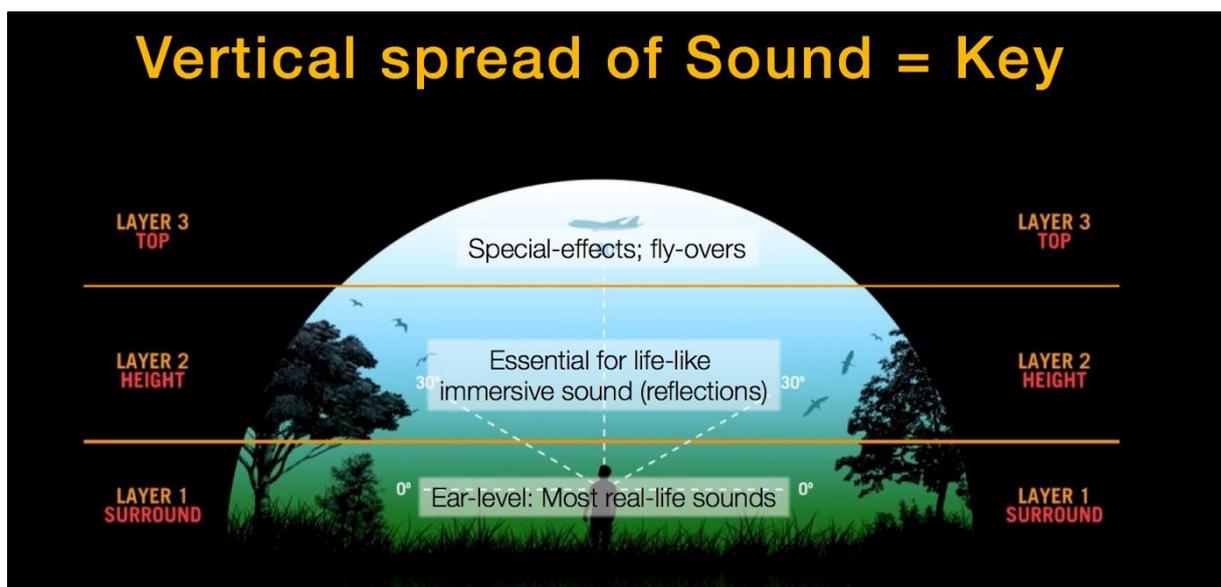


Figure 4 – Vertical spread of sound

This spread of sound in the vertical axis resulted in the speaker layout that he designed for cinema theaters (Auro 11.1 up to AUROMAX 26.1). It creates coherent sound fields in the vertical axis in front and all around the audience, creating also a much larger sweet-spot experience.

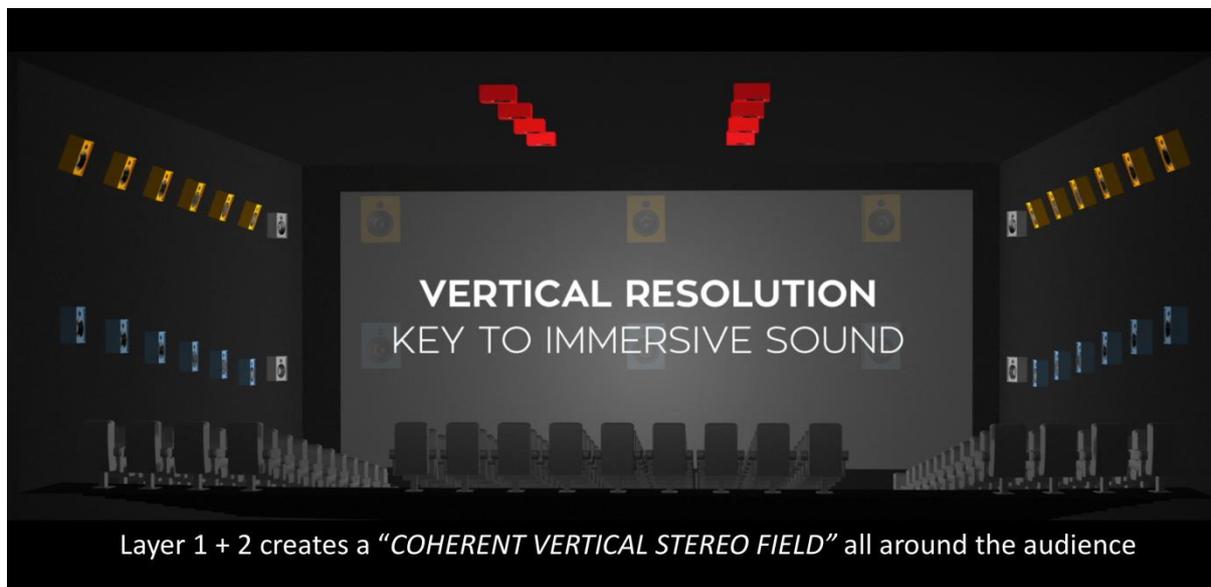


Figure 5 – Vertical resolution

5. Auro-3D's “vertical stereo field on screen” as part of the format's concept.

Auro-3D has also a “coherent vertical stereo field on screen” which is unique to the Auro-3D format. It allows more depth and transparency coming from the screen channels as well as more coherence with the objects on screen. Most sound energy is coming from the screen channels so it really makes sense to go for the best screen sound which is based on this vertical stereo field on screen. It will additionally create more ‘place’ for dialogue which is enhancing its intelligibility, also important because the dialogue track is still in immersive sound movies the backbone of each mix.

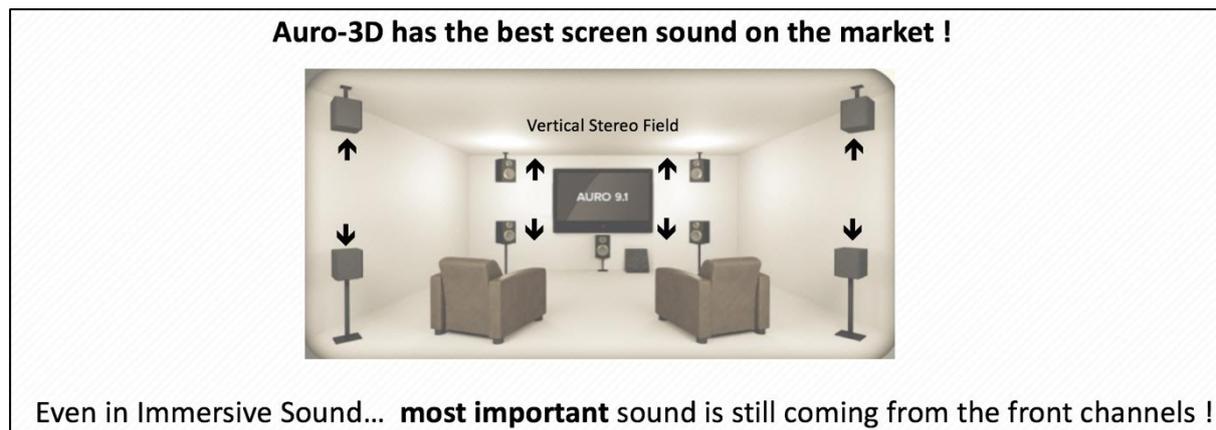


Figure 6 – Front channels usage

The same concept of the “vertical stereo field around the audience” goes for Auro-3D into home cinema. Even an Auro 9.1 speaker layout creates a total compatibility of the immersive experience from a big cinema theater into a small home cinema or even a TV.

Wilfried mentioned that even in cinema theaters where a 30° angle in the vertical axis is mostly impossible for the screen channels, it is better to have a 10° angle with 2 layers on screen compared to the traditional one layer (as Dolby Atmos and DTS:X). The transparency that can be created by the vertical plane of sound on the screen is just amazing. Some key engineers in Hollywood found that one of the biggest advantages of Auro-3D format while it enhances the screen sound in which now hundreds of sounds are coming from just a few channels creating so much comb-filtering and sounds getting masked. Spreading those sounds create more transparency and easier for our brain to analyze the complex sound field. In complex action scenes, very often are many details of the music track getting masked by the loud sound effects. The ability to spread those sounds create more emotion because the music has more clarity and gets more impact.

So if people just think that by placing the height speakers in between the recommended Dolby Atmos specs (45 to 55°) and the Auro-3D specs (25 to 35°) to achieve a good compromise for both formats, they make a mistake in their thinking because:

- 1) they kill the vertical natural coherence and as such will not achieve a natural immersive sound as intended by the creators of Auro-3D content.
- 2) they will not have a coherent sound field around the screen which might result in very funny effects. The sounds which were meant to be on the top of the screen, might suddenly sound too much overhead (this can be very strange with e.g. music which is very often well present in Auro-3D's height channels).

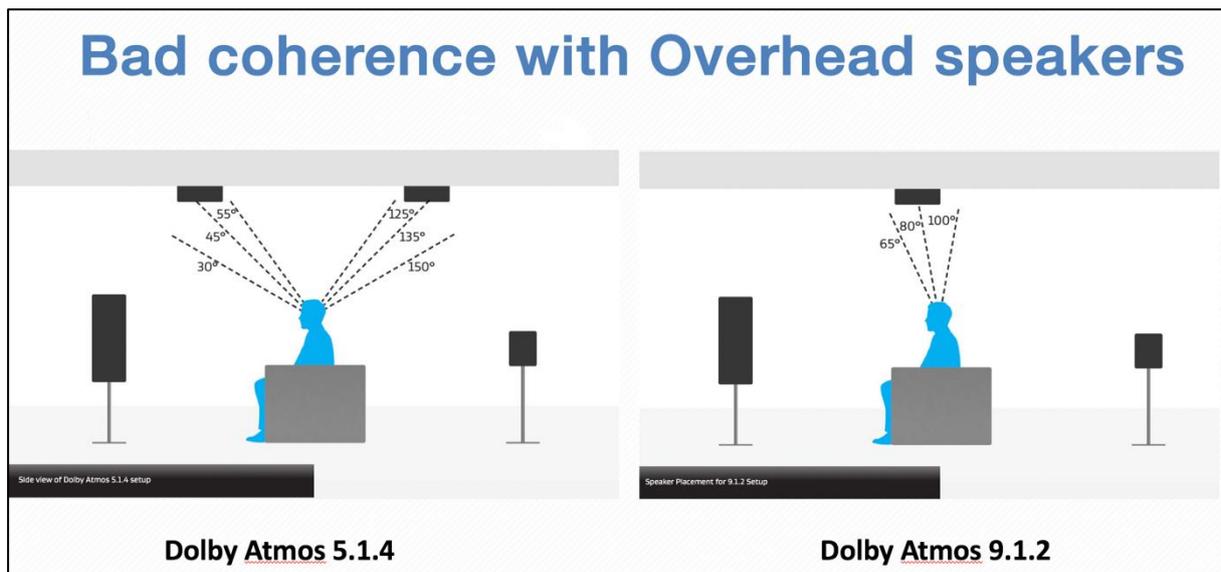


Figure 7 – Dolby Atmos Overhead speaker layouts

In case if only 2 overhead speakers used, Dolby's specs show an ideal 80° angle. In case 4 overhead speakers are used the angles are ideally between 45 and 55° front and 125° and 135° back. The good news is that Dolby expanded later their specs with the 30° angle as known from Auro-3D (see dotted line in the 5.1.4 design).

Note also that formats with 2 overhead speakers only (like Dolby/DTS 5.1.2 or 7.1.2 or 9.1.2) are NOT able to reproduce a 3D space for which at least Auro 8.0 is required (2 quadraphonic layers above each other with ideally an angle of 30° above ear level position of the lower layer) which is like a cube with in each corner a speaker (NB. the "cube" is used for Auro's logo).

6. Rectangular based system layouts versus circle based system layouts

Additionally the difference is also the setup in which Dolby Atmos speaker layouts are based on a rectangular shape while Auro-3D is based on a circle (as it was defined by the 5.1 ITU standard).

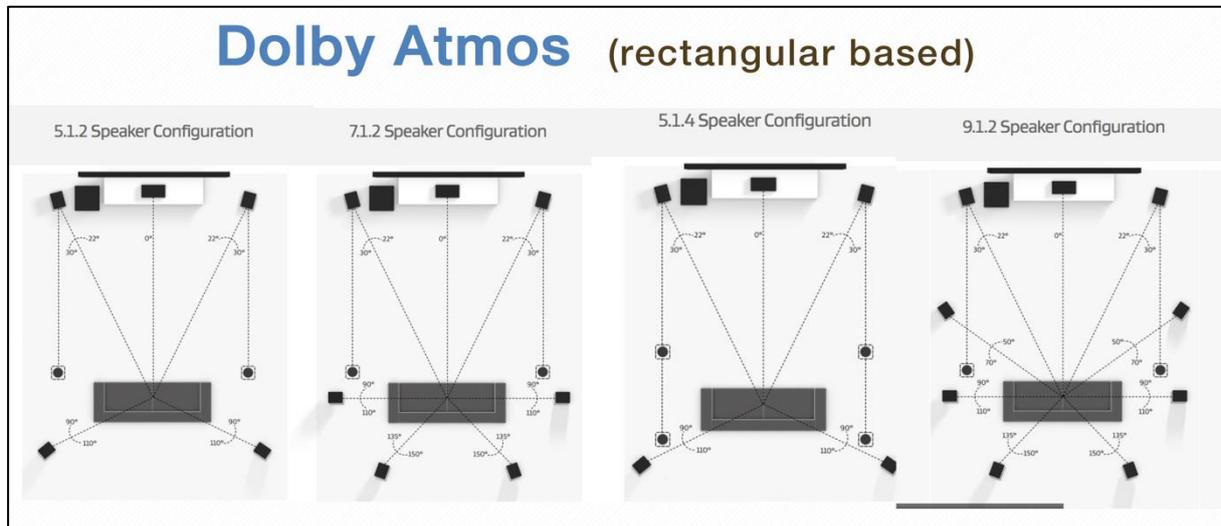


Figure 8 – Rectangular based system layouts: Dolby Atmos

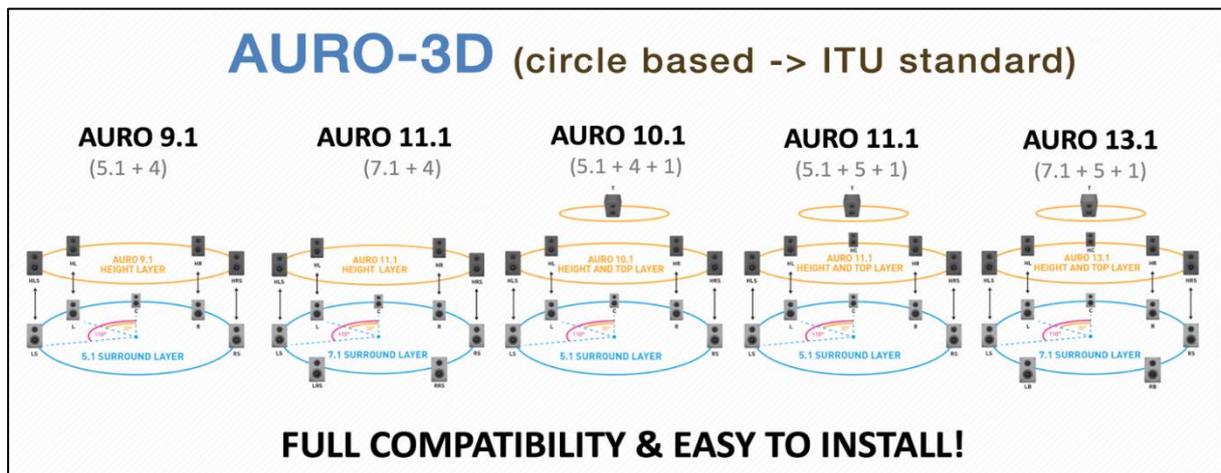


Figure 9 – Circle based system layouts: Auro-3D

7. Tilt of the elevated speakers

Another difference between Dolby Atmos and Auro-3D is the direction of the elevated (height or overhead) speakers. Dolby Atmos is directing the vertical directions of the speakers to the listeners head while Auro-3D is having the crossing point just above the listeners head in order to create more spatial effect as well as a larger sweet-spot (more people can hear the same immersive sound experience as intended by the creators).

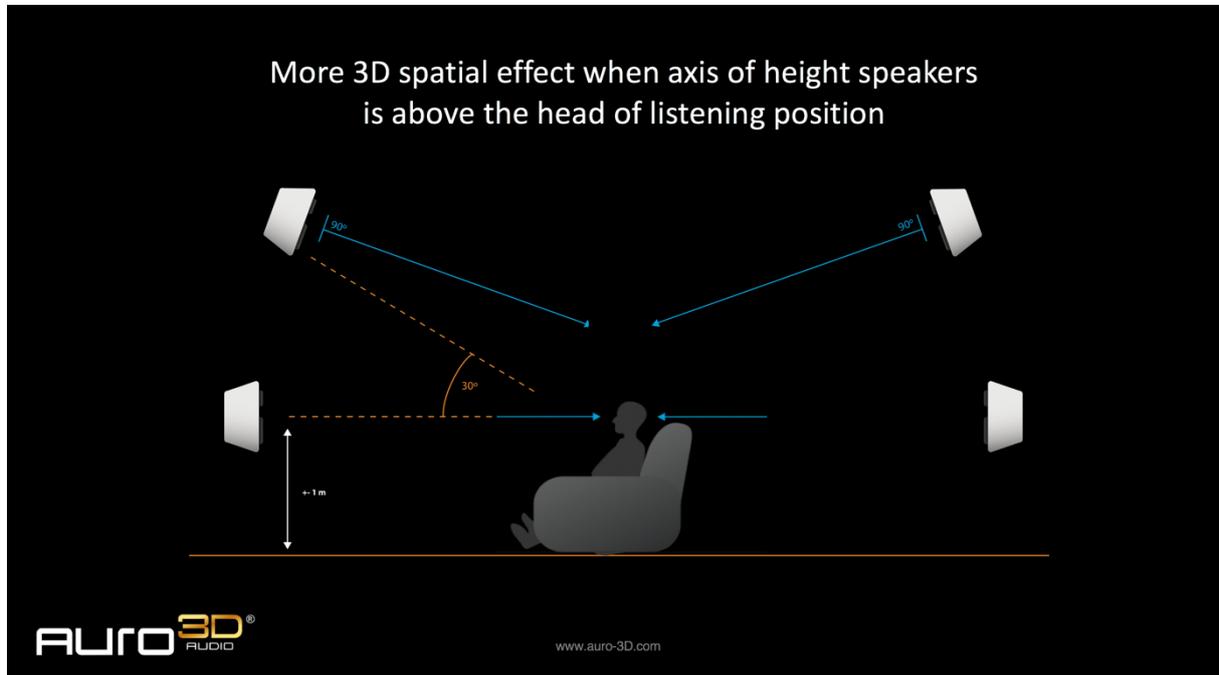


Figure 10 – heights crossing point above listeners position with Auro-3D

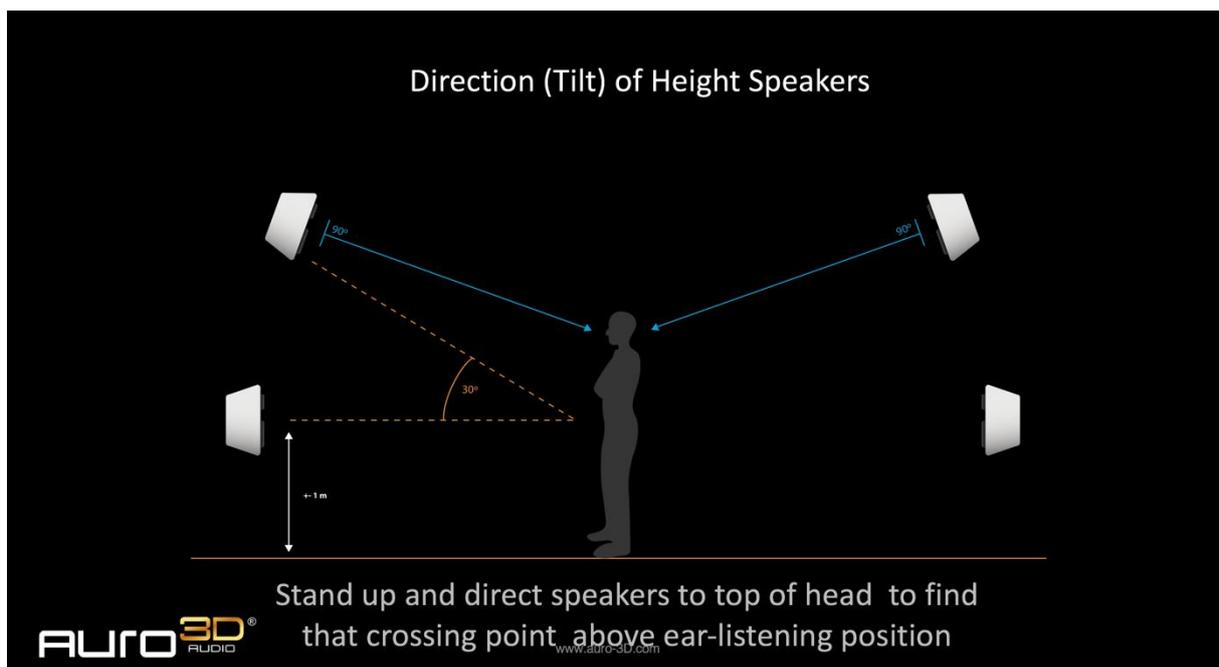


Figure 11 – direction of the elevated speakers with Auro-3D

Auro-3D is ideally built with a 5.1 setup in the lower layer and with Front Heights and Surround Heights in the upper layer. The Heights loudspeakers are classically mounted vertically above the loudspeakers of the lower layer.

For the listening position, a height angle of 30 degrees should be observed if possible, taking into account the remarks as mentioned above. But 30° on ITU (distance of each speaker is the same) results in a smaller vertical same angle when seated at 2/3 position of the room (as this is typical in many home cinema theaters).

For the above reason, Auro-3D allowed to put the Height Front speakers in the ceiling as long as the distance of the Height speaker is not shorter to the listener position as the distance of the ear-level speaker. As such, the “vertical sound field on screen” will be maintained as best as possible.

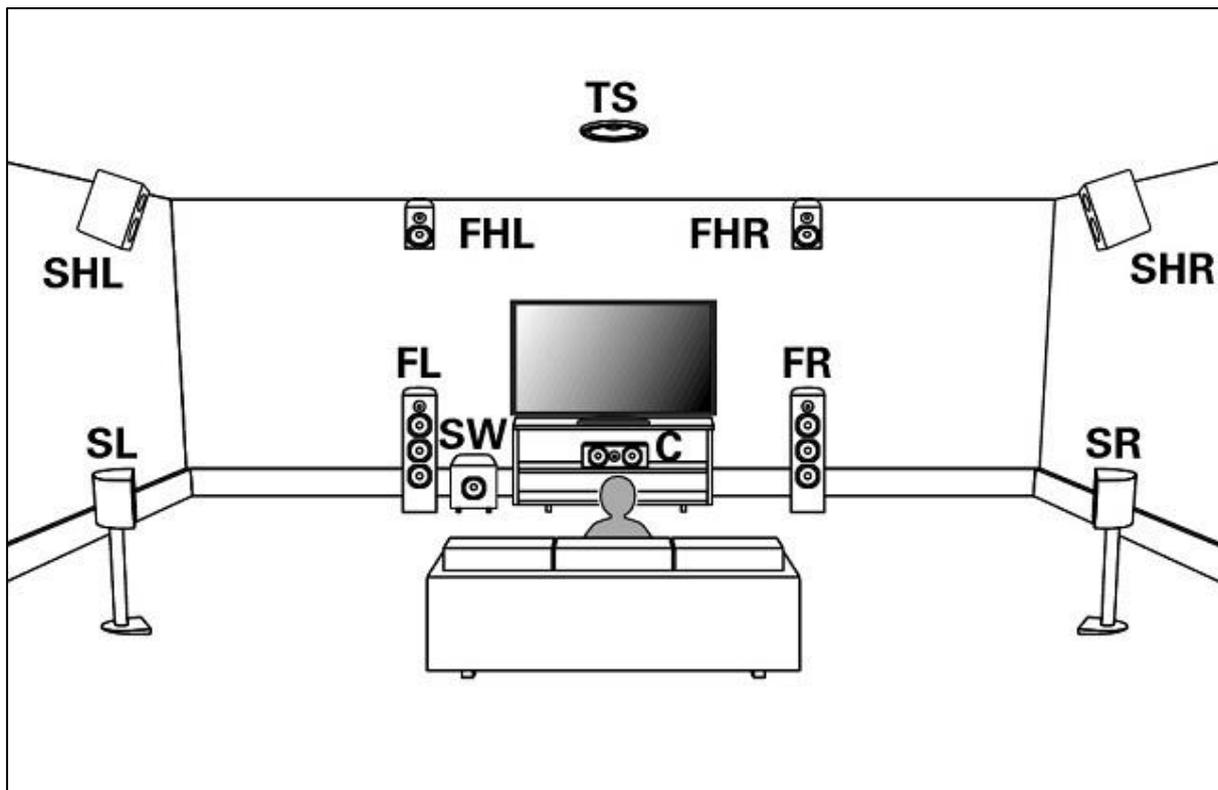


Figure 12 - 5.1.4 Auro-3D Setup with Surround Heights - © D&M Holdings Inc. All Rights Reserved.

As with the other 3D audio formats Dolby Atmos and DTS:X, the speaker configurations supported by Auro-3D can be viewed in the White Papers and Installation Guides:

Link: [AURO-3D HOME THEATER SETUP Installation Guidelines](#)

Link: [Dolby Atmos® Home Theater Installation Guidelines](#)

Link: [Trinnov Guide: Recommended Loudspeaker Positions For Screen Loudspeakers](#)

The subsequent expansion of the Auro-3D standard from Surround Heights to Rear Heights is not included here yet.

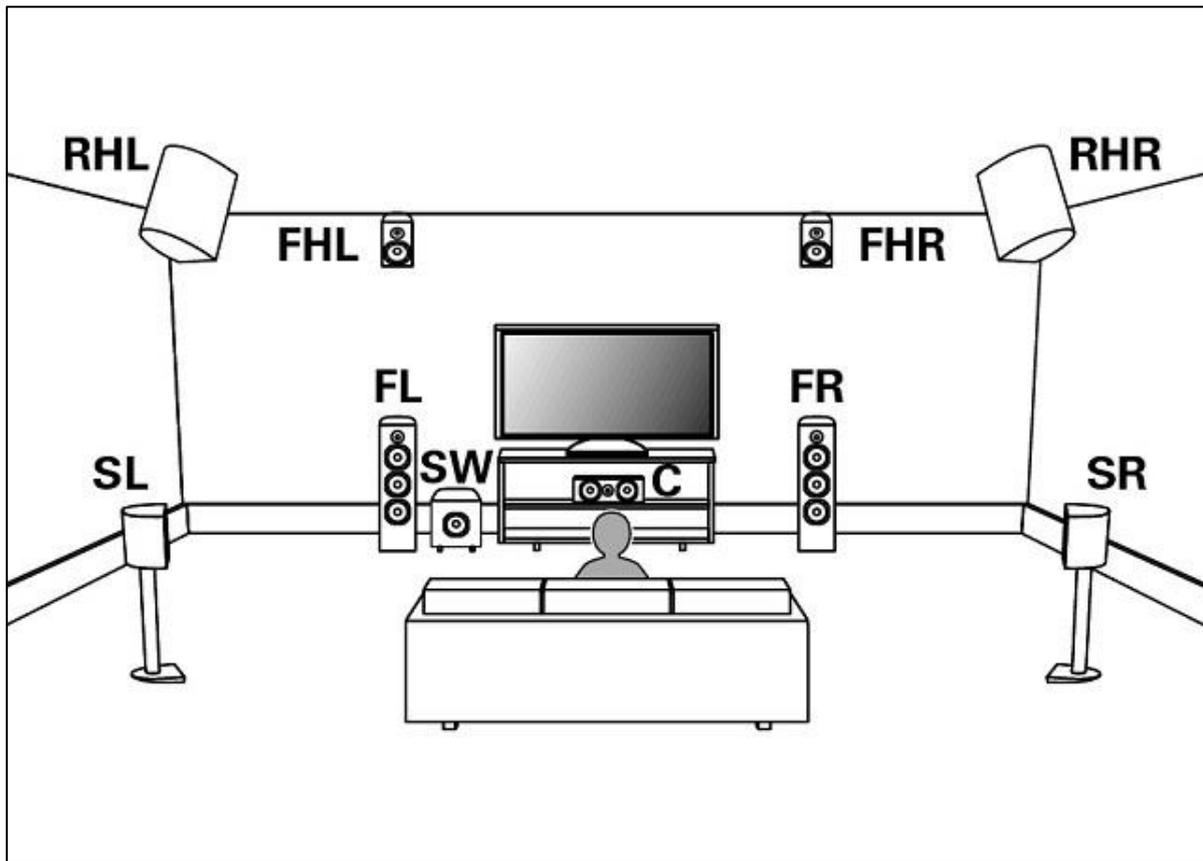


Figure 13 - 5.1.4 Auro-3D Setup with Rear Heights - © D&M Holdings Inc. All Rights Reserved.

In addition to this classic AURO 9.1 or AURO 10.1 (with additional Top Surround / Voice of God) are based on 5.1 but can also be extended to a 7.1 in the base including the surround back channels. In addition to the four Heights loudspeakers (upper layer) and the Voice of God (top layer), an additional Center Height loudspeaker is added in the top layer, which extends the entire setup to AURO 13.1 and 7.1.6 respectively.

In addition, the Auro-Matic upmixer has the two new setting modes "Language" and "Movie". The Auro-Matic can now be applied to native Auro-3D for the first time (Auro 9.1, Auro 10.1) to use all available speakers. Thus a maximum of Auro 13.1 is possible. The function can of course also be deactivated for purists.

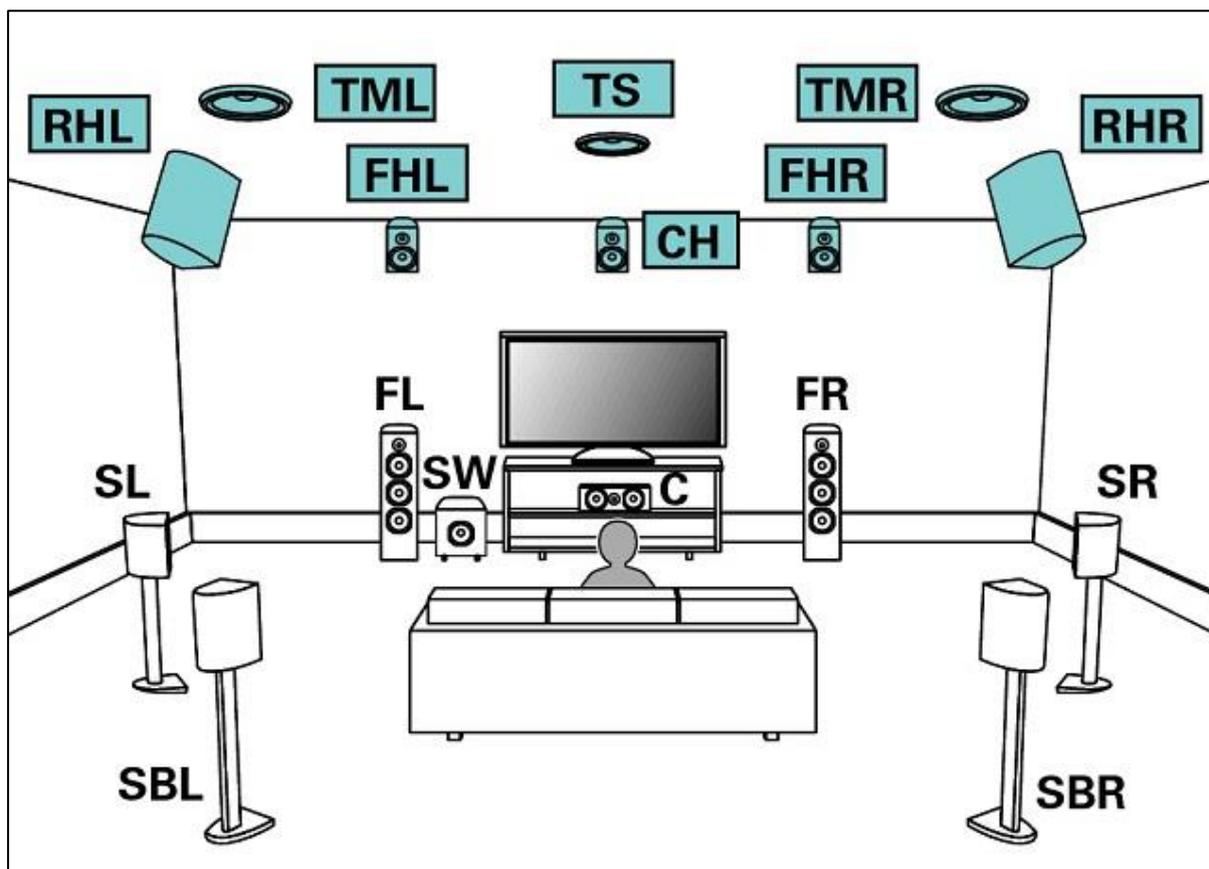


Figure 14 - 7.1.6- Auro-3D Setup with Rear Heights - © D&M Holdings Inc. All Rights Reserved.

This "extended" Auro-3D is currently only used in a few AV-bolides, e.g. the [Denon AVC-X8500H](#), the [Marantz AV8805-Preamplifier](#) or the much more expensive [Trinnov Altitude AV Sound processors](#).

Since 2020 also Denon AVC-X6700H and Marantz SR8015 will support the 7.1.6-Auro-3D-Layout.

8. Setup with Front Heights and Rear Heights

Since I didn't want to give up the possibility to play native Dolby Atmos, a setup had to be built, which is defined for all three formats. Of course, compromises have to be made, but in my opinion they are justifiable and still lead to an excellent result. The setup described in the following is currently implemented for my own home cinema (Link: [\[Baubericht\] Heimkinobau "Binaptikum 4K" - 7.2.4 Keller-Heimkino für Auro 3D, Dolby Atmos und DTS:X](#)).

The configuration has meanwhile been extended to a 7.2.6 setup, again with Auro-3D as well as Dolby Atmos support (as shown above, in *Figure 14 - 7.1.6- Auro-3D Setup with Rear Heights*).

As basis a setup with Front Heights and Rear Heights has to be installed, which is supported in all three formats Auro-3D, Dolby Atmos and DTS:X. Thanks to the subsequent Auro-3D configuration expansion from Surround Heights to Rear Heights, parallel operation with the already defined Front Heights/Rear Heights-Dolby Atmos setup is now also possible. Dolby Atmos also theoretically allows a 5.1.4 configuration with Surround Heights in the AV processor setup, but in Atmos mode the Surround Heights remain unused and sound is only output via the Front Heights.

In order to stay as close as possible to the original Auro-3D setup, the elevation angles of the Heights speakers are set to 30 degrees for a compromise solution. If more value is placed on Dolby Atmos, the

elevation angle can be increased in favor of an optimal Atmos setup, which recommends 45 degrees as the optimal angle. Other users, for example, suggest values of about 40 degrees elevation angle. But please be careful with such big angles, because the sound immersion depends in relevant way on the room height and screen size.

According to Auro-3D specifications, the Heights loudspeakers are to be positioned exactly vertically above the front loudspeakers and surround loudspeakers of the lower layer as standard. Unfortunately, with a standard ceiling height (around 2,00 - 2.30m, only elevation angles near 20 degrees or even less are possible for the front heights at the seating position. It's also clear that the elevation angle depends on the seating position, sweet spot and screen distance.

A remedy is to move the front heights in the direction of the listening position, which increases the elevation angle. The original wall position gives way to a ceiling position. Please make sure that the distance "Height speaker seating position" does not differ by more than 10% from the distance "Front speaker - seating position". If the distance at the sitting position to the front loudspeaker is exactly 3.0 meters, for example, the height loudspeaker may have a minimum distance of 2.70 meters (direct distance ear to loudspeaker). Regarding the 10% rule, see also Auro-3D Installation Guidelines, "3.4.1 Low ceiling".

In my own home theater, if the heights were positioned directly vertically above the front speaker, only an elevation angle of about 18 degrees would be possible, which is due to my ceiling height of about 2.20 meters. By moving and pulling the heights into the room, they can be brought to the 30 degree elevation required by Auro-3D, but then they have to be positioned on the ceiling.

9. The Different Angles: Elevation Angle vs. Loudspeaker Orientation

The *elevation angle* is the exact position of the loudspeaker measured in height relative to the listening position.

In simple terms, this refers to the angle between the horizontal (view to the front) and the line of sight to the high-frequency loudspeaker (line of sight to the high-frequency loudspeaker diagonally above). For details and calculation see separate section "The elevation angle".

In contrast, the alignment angle of a loudspeaker must be strictly separated from the elevation angle! This is the angle at which a loudspeaker is angled or twisted towards the listening position. Of course, this angle also depends on the dispersion characteristics of the loudspeaker. For example, there are very wide radiating drivers or drivers with strong bundling. Switchable treble loudspeakers are also worth mentioning here (e.g. [Dali Alteco C-1](#)).

Deflection and chassis radiation angles can also be added. An elevation angle that only determines the height position of the loudspeaker cannot be influenced, increased or even replaced!

The alignment angle of the high-frequency loudspeakers using Auro-3D as an example is clearly defined in the Setup Guide. The listening axes of the Front Heights and Rear Heights tweeters with an elevation height of 30 degrees are aligned in the direction of the listening position so that they cross at ear level of an upright person at the listening position. In a seated position, this corresponds to a crossing point about 20-30cm above the head.

10. The Elevation Angle

The elevation angle mentioned above is very important for the construction of the upper layer. This is true for Dolby Atmos and much more for Auro-3D. While Dolby Atmos works with top loudspeakers at 45 to 55 degrees elevation, Auro-3D uses average 30 degrees elevation.

In the following, the elevation angle is explained in more detail using Auro-3D as an example:

The human ear can locate noises and sounds from the front much better than from above or behind. It is extremely important that the lower layer can still be distinguished from the upper layer acoustically. Auro-3D uses elevation angles of around 30 degrees for the Heights speakers for best immersion results. If this elevation angle drops below 15 degrees, then a too large is located above. If the angle is too small, it can result in more comb filtering especially if the original content recordings were based on a coherent vertical sound field of about 30°. In case only 15° is possible in the front screen channels, then at least a third layer is needed in order to create an immersive 3D sound experience.

From the picture below it becomes clear that you can calculate the **Elevation angle α** (shown in orange in the picture) if you determine the **difference between ceiling height/seat height h** and additionally the **distance in the horizontal direction to the loudspeaker position d** .

The elevation angle α , which applies to the listening position (spanned between legs **d** and **c**), is identical to its alternate angle α , which is located on the ceiling of the high-frequency loudspeaker (spanned between legs **b** and **c**).

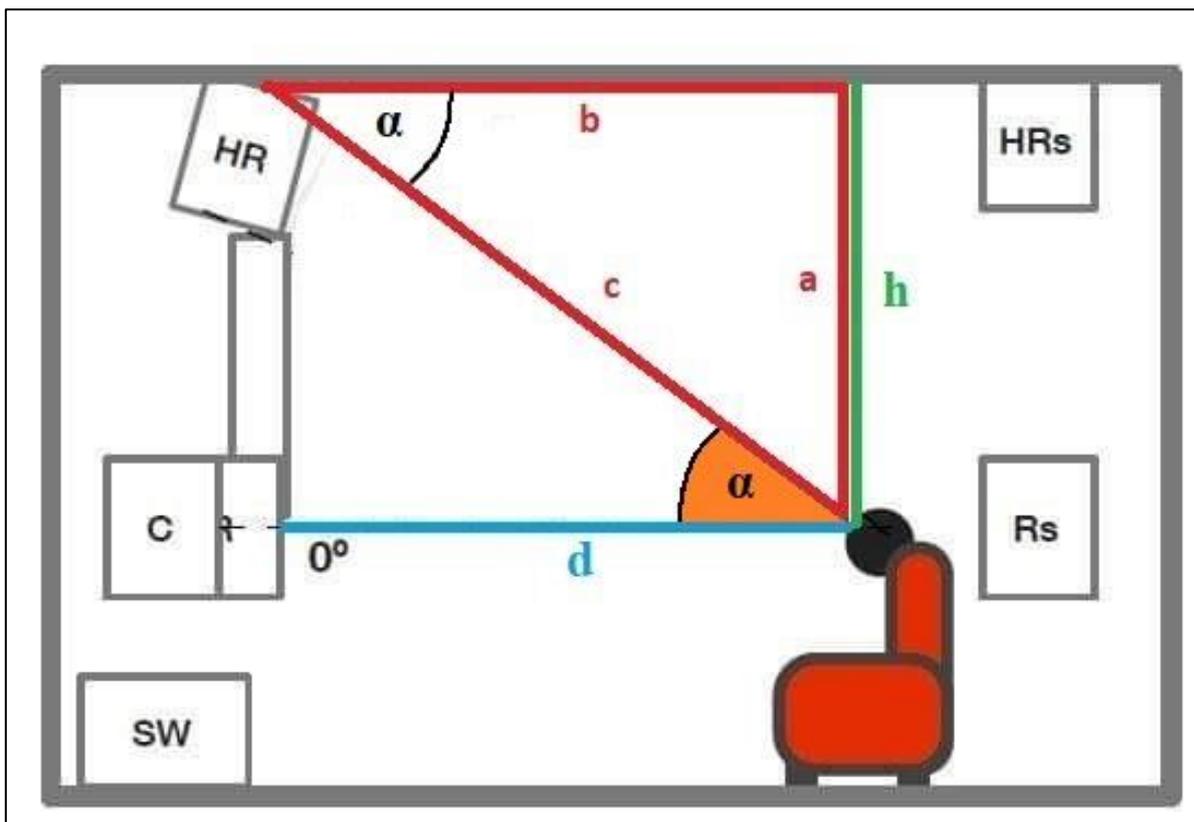


Figure 15 – Calculation of the Elevation angle

Note: To simplify matters, the exact position of the tweeter in the high-frequency loudspeaker has not been taken as the angle reference point. If, on the other hand, you want to calculate it absolutely accurately, you have to subtract the distance between the tweeter and the ceiling from the height h (or distance a).

It applies:

Elevation angle α (for two given cathets **a** and **b**) (red triangle and red designations):

$$\alpha = \arctan(a / b)$$

If **a** and **b** are the same length, the elevation angle is 45 degrees (which is the default for Dolby Atmos).

Form the equation to get the distance **b**, how close the heights have to be pulled to the seat.

$$b = a / \tan(\alpha)$$

is obtained with a given elevation of 30 degrees for the example Auro-3D:

$$b = a / \tan(30^\circ)$$

Since the ceiling height is actually always unchangeable, e.g. 2.40m, and provided that the ears are then in sitting position at e.g. 110cm height: Distance to ceiling $h=130\text{cm}$

$$b = 130\text{cm} / 0,57735 = 225\text{cm}$$

Consequently, the loudspeakers must be pulled up to 2.25m to the sitting position in order to raise it to 30 degrees elevation.

To very quickly check an Auro-3D setup for correct elevation angles or to find the ideal horizontal distance of the Heights speakers to the listening position, you can use the following quick check:

1. Take your preferable sitting listening position (sweet spot).
2. Measure the distance of the ears vertically upwards to the ceiling and memorize this VALUE
3. Insert the VALUE in the following equation and calculate:
RESULT = VALUE divided by 0,57735
4. RESULT is now the horizontal distance from the listening position to the loudspeaker on the ceiling (measured from the ceiling!)

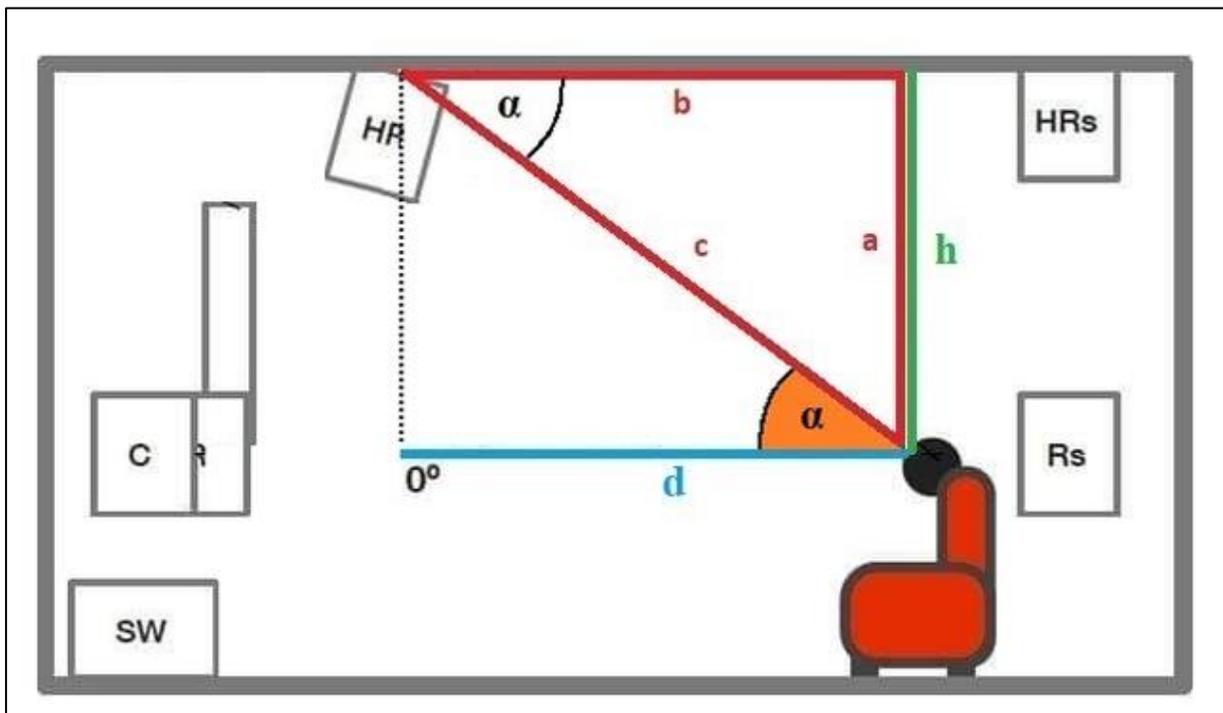


Figure 16 – New Heights position to comply with the correct Elevation angle

For further clarification the following picture shows the distances **c** and **d** and the elevation angle **α** in the three-dimensional room to compare it with the above 2D-view picture:

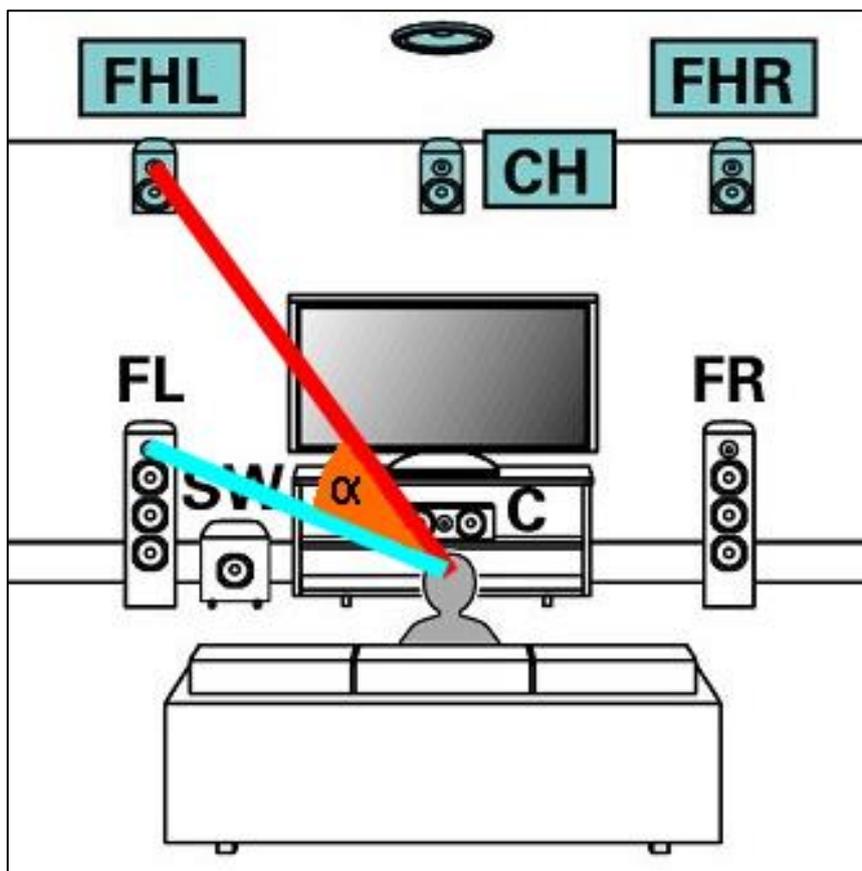


Figure 17 – Elevation angle in the three-dimensional room

[11.1 Appendix: Overview of current AV devices with the enhanced Auro-3D version](#)

Since there are always questions about Auro-3D capable devices, here is an overview of the AV devices that currently support Auro-3D in the extended version. Previous years' models are not included.

It should be noted that there are basically two different versions of Auro-3D, which differ in the number of supported speakers:

Standard Auro-3D: maximum 9.1/10.1 as 5.1.4 and 5.1.5, respectively.

Extended Auro-3D: maximum 13.1 as 7.1.6

The standard Auro-3D does not support Surround Backs or Center Height.

The extended Auro-3D is installed in the following AV devices:

Denon

AVC-X8500H (13-Channel Processing)
AVC-X8500HA (13-Channel Processing)
AVC-X4700H (11-Channel Processing, either 7.1.4 or 5.1.5)
AVC-X6700H (13-Channel Processing)
AVC-A110 (13-Channel Processing)

Marantz

SR7015 (11-Channel Processing, either 7.1.4 or 5.1.5)
SR8015 (13-Channel Processing)
AV8805 (13-Channel Processing)
AV7706 (11-Channel Processing)

Arcam

AVR10 (12-Channel Processing, either 7.1.4 or 5.1.5)
AVR20 (16-Channel Processing)
AVR30 (16-Channel Processing)
AV40 (16-Channel Processing)

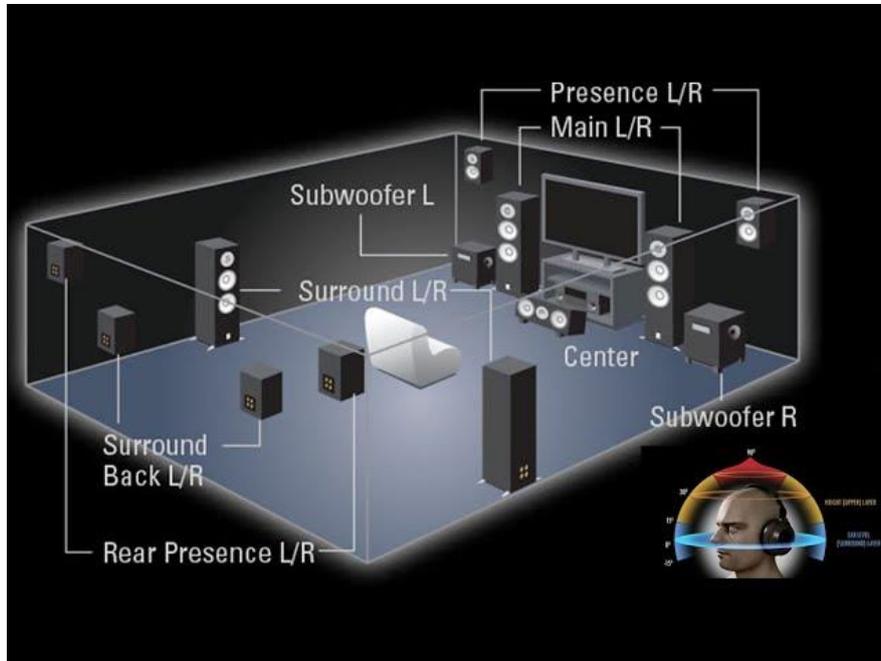
Of course, the high-priced preamplifier models from Trinnov, Stormaudio, Datasat, Lyngdorf, JBL Systems, etc., also support the extended Auro-3D.

In Denon/Marantz models, only the new DSP chips, which were originally exclusively installed in the X8500H and AV8805, enable the support of the surround back channels.

11.2 Useful information videos

1. Impressive interview on the topic by Patrick Schappert (Grobi.TV) with the American web site Audioholics:

Link: [Overcoming Problems with Bad Immersive Audio Mixes](#)



2. Presentation of Roland Krüger (Sound United, german)

Link: [Von Dolby Atmos bis Auro3D - alles unter einem Hut mit einer Lautsprecherkonfiguration](#)



3. Wilfried Van Baelen explains everything around the concept and use of the Auro-3D format. Learn how Auro-3D was born and about its unique benefits.

Link: [Wilfried Van Baelen explains everything around the concept and use of the Auro-3D format](#)



4. GROBI-TV: Live Chat with Wilfried Van Baelen

Link: [GROBI-TV: Live Chat with Wilfried Van Baelen](#)

