

Barco

Auro-3D

A new dimension in cinema sound

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INTRODUCTION

The introduction of digital projection in cinema theatres has spurred a revival in 3D movies. The first was 'Chicken Little' in 2005, and now – according to box office returns – they're here to stay. The image quality provided by digital cinema systems provides the immersive 3D experience that moviegoers have been missing for decades. But in contrast to this revolution of the visual experience, cinema audio has been evolving very slowly. In fact, other than adding a few more speakers to surround the audience with sound, the past 20 years have brought forth no significant innovations that have been able to make the aural experience as life-like and immersive as 3D imagery ... until now.

3D audio is the next logical step required to usher in the ultimate motion picture experience. When experiencing 3D Sound, one realizes that an immersive sound field creates more of an emotional response in the audience than image alone. Sound is related to emotion. Even when environmental sounds are heard unconsciously, they can have an impact on our emotional attitude and behavior.

The importance of sound – for business applications as well as for private individuals – has been greatly underestimated. People feel connected with the environment through sound – and the more natural the sound, the closer the connection. Furthermore, neurologists and sound engineers have long proven that sound can strongly influence the brain and the body.

As George Lucas put it: sound is 50% of the movie experience. Still, the industry remains uncertain as to how to properly implement and use a new 3D sound experience. Auro-3D is the ideal, state-of-the-art solution because it integrates the full 3D experience into existing technology and standards with a flexibility and quality never achieved before. This new format was first showcased at the AES Conventions in Paris and San Francisco in 2006 – and it has only improved since.

Providing 3D listening formats that are compatible with current standards is just one of the contributions that Auro-3D has made. But what about the technology that will permit this new 3D format to be placed within the market's existing distribution architectures and make it compatible with all forms of multimedia?

In this white paper, we'll explore the nature of human hearing, the shortcomings of current sound systems, and how Auro-3D addresses these shortcomings and the opportunities it can offer to your production pipelines and to commercial movie theatres.

THE PERCEPTION OF SOUND

Our brains perceive pictures very consciously, whereas sound is perceived rather unconsciously. Therefore, sound is sometimes considered to be less important, although film producers assert that sound creates at least as much emotional response as images do.

Full True 3D Sound reproductions require a speaker layout with three spatial axes (X = width, Y = depth, Z = height) to produce true "dimensional sound in space". This means that simply the addition of height speakers will ensure the reproduction of real 3-dimensional sound. Consumers, industry leaders and experts clearly see the evolution in audio entertainment evolving from a point source format (Academy Mono) to a single dimensional format (Stereo), later to the popular 2-dimensional format (Surround Sound), and finally to the ultimate 3-dimensional format: "A Full 3D Audio Format" that is compatible with downstream multimedia markets.

Previous generations listened to mono systems, whereas the post-WWII generation grew up with technologies like stereo sound (which was spurred on by the invention of the television). The current generation is growing up in a digital 'surround sound' environment. Today's digital surround sound can be produced by two different systems that play back this 'ambient sound': the "Real" 5.1 System, which uses one speaker per channel, and the "Virtual" Surround System which is usually matrixed and then derived from a stereo source.

The speaker layout of 5.1 Surround Sound, which is placed in a 2-dimensional plane (x= width, y = depth), was sold to the consumer as *the* solution for an immersive sound environment, but it did not fully deliver that experience. Furthermore, 6.1 and 7.1 surround releases still fail to fulfill this expectation, as they merely expand the depth of the horizontal plane around the listener. So, the current Surround Sound concept still has many shortcomings and is not able to immerse the listener in a "True Sound environment" (especially when you consider all that the new 3D digital technology can deliver). Whether that listener is gaming, watching a movie at a local theater, listening to music, or watching a sports event, the expectation of a more immersive sound field remains unfulfilled.

Full True 3D Sound must be a unique experience that places the listener as the main observer in a virtual (close to reality) world. The listener must be positioned in the "middle" of the action and feel as if he or she is part of it. 3D Sound reproduction, which simulates the natural ambient sound experience much more closely than current surround systems do, also promotes greater acceptance of an immersive experience, since our brains are designed to experience enveloping sound rather than the 2-dimensional point-source sound reproduction today's systems provide.

Due to the technical limitations of current (2-dimensional) sound systems, and the fact that recently proposed solutions are incompatible with existing standards, no commercially viable solution for providing 3D sound has appeared on the market ... yet.

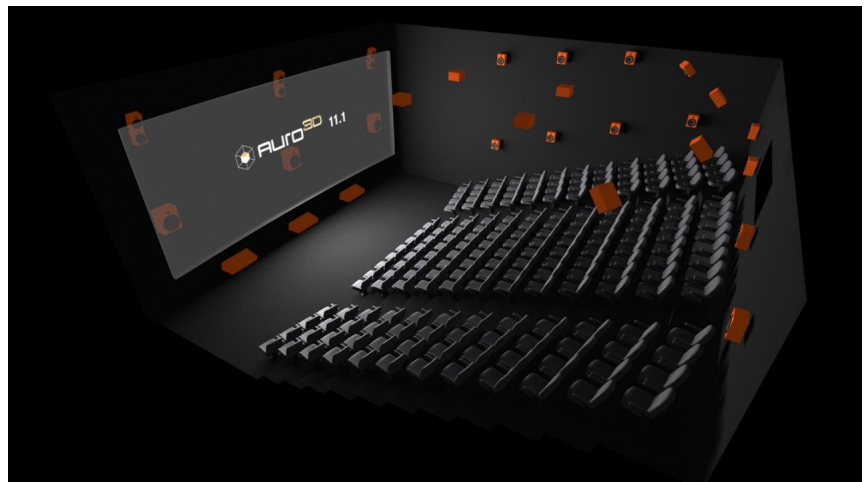
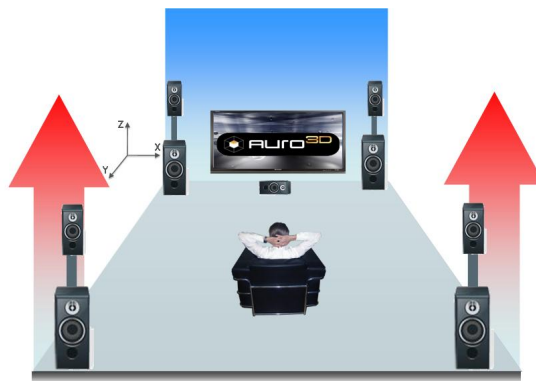
The multimedia world is moving fast and is preparing a giant step to allow consumers to experience a higher level of entertainment by integrating 3D technology into gaming, broadcasting, cars, home-

cinema, theaters, music, mobile phones, streaming, PC, and other content.

However, as history has shown, revolutions in entertainment technology always begin at the theater. 3D audio will be no exception.

INTRODUCING THE AURO-3D FORMAT

Full 3D sound in space can only be reproduced by using at least 8 speakers, positioned at the 8 corners of a cube. By adding a center and LFE channel, the smallest full 3D sound speaker layout is a 9.1 configuration as defined by the Auro-3D Format, which is fully compatible with existing 5.1 systems. This is illustrated below for a home cinema and an 11.1 configuration for a movie theater setting.



This basic speaker layout is very straightforward and based on the 5.1 standard: a Height speaker is added on each "corner" of a 5.1 surround setup. This results in a two-quadraphonic layer system, with the addition of a Center Speaker and a LFE (Subwoofer) channel to be compatible with the 5.1 standard. It uses the smallest number of speakers to reproduce Full True 3D Sound, while remaining compatible with today's main standards: Stereo and 5.1 Surround.

The full Auro-3D speaker layout is defined for up to 13.1 channels, with 11.1 being the ideal solution for environments such as a commercial movie theater. Each sub-layout has its own fixed setup. It is important that we do not confuse the market with different layouts for a certain number of channels. While offering various configurations (each one is appropriate for a specific environment), they all offer the same basic layout.

The Auro-3D speaker layouts 9.1 up to 11.1 are based on the 5.1 Standard:

- 9.1 Auro-3D: + 4 height channels (one above each corner speaker / array)
- 10.1 Auro-3D: + 5 height channels (+TS = "Voice of God" channel)
- 11.1 Auro-3D: + 6 height channels (+ Height Center)

The Auro-3D speaker layouts 12.1 and 13.1 are based on the 6.1 or 7.1 Standard:

- 12.1 Auro-3D = 11.1 Auro-3D + Rear Center (6.1)
- 13.1 Auro-3D = 12.1 Auro-3D + Height Rear Center

NOTE:

Using the Auro-3D Codec, the 11.1 mix can be encoded into a 5.1 mix. There will also be an upgrade path to allow a 12.1 Auro-3D master to be encoded in a 5.1 mix.

With standard surround sound or wave field synthesis based systems, the speakers are located only in the horizontal plane (= 2D), so this does not create the height effects that lead to a psychoacoustic sensation of being in a virtual environment. By applying real 3D Sound – the most natural reproduction of sound – you create more than just a new listening experience: this is a truly immersive experience that encapsulates the listener within the action. Direct (objects) and indirect (ambient) sounds coming from around and above the listener are created by using acoustical reflections in 3D, allowing the mind to correctly position the sources of the sounds.

This makes 3D Sound the perfect match for the digital 3D *visual* experience.

THE ADDED VALUE OF AURO-3D IN CINEMA

The sound ecosystem in cinema has a number of players. The studios want to create the strongest possible story. The creative professionals on-set and in post-production want to add their unique contributions to that story by using the latest and most effective production technologies available. And finally, the exhibitors want to bring this story to the largest possible audience by creating the most immersive experience. Auro-3D helps each of these players achieve their goals.

STUDIOS

Of course, every movie is a story that is a meaningful artistic journey for those who create it, but it is also a business venture for the studios. It has a schedule, a certain level of quality, and a budget. Through its unique compatibility with existing formats and standards, Auro-3D can empower the story without compromising the budget. Adding 3D sound through Auro-3D raises a movie's total sound budget by not even 1%. While 3D audio technology may be regarded as a revolutionary disruptive technology, the tools available with Auro-3D allow for easy integration into existing post-production processes. Just like distribution today, only 1 print master is required, and that single distribution DCP supports all formats including all downstream release formats. 3D with a 2D budget! This also applies to DVD and BluRay releases, since the Auro-3D stream can fit into existing 5.1 streams.

Auro-3D provides truly immersive 3D sound while being backwards compatible with existing standards. There is no “chicken & egg” problem, which has blocked the introduction of new technologies in the past.

The master mix is first artistically created in 11.1 for the main release into theaters. Next, the 11.1 mix is folded into a 5.1 release mix in a quick, but artistically supervised, mix-down session. Then, this 5.1 master is encoded with the Auro-3D (11.1) channel information to create the final 5.1 PCM (uncompressed audio) master used in distribution and, potentially, in all other downstream formats.

This upstream and downstream compatibility with current standards and production practices makes Auro-3D the best solution for next-generation audio and the only viable solution for the marketplace.

What's more, Auro-3D also introduces new creative opportunities. Studios can now re-release their classic titles in artistically created 3D sound up-conversions, a function that the Auro-3D codec can also provide. Something to be considered seriously as the idea of re-releasing classic films in 3D visual gains momentum.

While presentation technology has progressed to digital and then to Digital 3D, sound technology has not evolved very much in nearly 20 years. Auro-3D allows sound technology to “catch up” to the current visual presentation systems – bringing a total immersive experience to the movie-going public.

CREATIVE PROFESSIONALS

Creative professionals – such as the director, composer, sound designer, production sound mixer, recording engineer and re-recording engineer – bring their unique expertise and skills to a motion picture production. Their talents converge to take the story to a higher level. Being creative, they look for more degrees of freedom to help tell a better story. Being professional, they do this without compromising quality or performance. Auro-3D helps achieve these specific goals.

The artistic mix of the Auro-3D codecs gives creative professionals access to the greater freedom they are looking for, especially when creating a unique 3D visual experience. Having the capability to add 3D sound effects to support or enhance the visuals opens up a new level of creativity. Furthermore, this can be done without sacrificing the dynamic

range of the original PCM, ensuring that quality and control are maintained. Even when they apply some of the available automated mixing tools, they have the guarantee that the balance and sound color of their material are maintained.

EXHIBITORS

Exhibitors not only need to manage a multitude of movies coming onto their screens every couple of weeks, they must also manage and meet the increasingly sophisticated expectations of the thousands of patrons coming to their theaters expecting to enjoy themselves and escape the world for a little while. It's understandable that exhibitors will hesitate to re-invest in new equipment and re-design their auditorium layouts. But this is exactly where Auro-3D was designed to their requirements: upgrading from surround sound to true 3D sound is perfectly easy – you simply add height speakers to the existing footprint. Furthermore, Auro-3D sound processing is similar to, and compatible with, existing setups.

Another important consideration for exhibitors is the impact of this new technology. Yes, the effect is stronger, more immersive and more natural than surround sound – but will content be available to enjoy this on? And what about alternative content that was not made for 3D reproduction? All of these things were taken into consideration when Auro-3D was designed. As mentioned above, the standard is fully backwards compatible with existing standards, guaranteeing full support of all content. This guarantees compatibility with your pre-show and alternative content. There is also the capability to up-mix content: either in an artistic up-mix (as mentioned above in the production process) or in a more “Auro-Matic” manner, while still maintaining the balance and color of the original content.

Let's not forget the new opportunities Auro-3D could bring to exhibitors. With theaters investing in 3D, digital projection and 4K technology as ways to differentiate from the competition, imagine standing out in the crowd by pioneering “sound in 3D”! Not only will this help you differentiate from other exhibitors, it will also pull people away from their homes to dive into this new experience that's only available at their favorite movie house! With the 3D visual experience already one step ahead, this is the opportunity for exhibitors to update their sound installation and create the most complete motion picture experience for their patrons.

THE AURO-3D CODECS

Up to now, the only way to achieve the reproduction of multi-channel formats has been by means of so-called “Data Compression”. But the market is evolving, and the current trend is to move back to the original digital uncompressed audio format – called PCM (Pulse Code Modulation) – which avoids the use of Data Compression codecs. This is evident in evolving broadcast and BluRay specifications and even the DCI spec, which specifically calls for the use of uncompressed audio. This trend is occurring as the various “lossy” data compression systems for audio (Dolby, DTS, MP3, etc.) prove to be incompatible and extremely difficult to use while maintaining a philosophy of single format distribution. Moreover, compression formats can create sound distortion, causing a loss of fidelity and mental fatigue in the listeners.

Due to these shortcomings and the upcoming new trends and needs in the market, a highly intelligent new invention, called the Auro-3D Codec, has been developed over a number of years. With many advantages compared to other data compression based codecs, it is also easy to adopt because it relies on the uncompressed digital audio standard (PCM) that is integrated in every audio-related device.

To add a 3rd dimension to a sound-scape, a solution is needed to fit the artistic mix in the available channels. For this reason, people think they must continue with data compressed formats. However, these suffer from too many compatibility issues, latency, distortion, and a loss of fidelity created by perceptual masking. So, for many reasons, everybody would like to move back to the uncompressed quality of PCM, but they worry about limitations in bandwidth.

All these issues are solved due to the way the Auro-3D codec allows mixers to create an artistic and dynamically controlled PCM signal that contains two or three other PCM signals without any audible loss. The master of that mixed information is still a standard PCM signal with the same sample rate as the original mixed tracks. This means that, in the PCM domain, we can create multiple distributions in just one 5.1 master. This 5.1 PCM master carries these formats as unperceivable metadata and can be played back on every audio device that supports 5.1 PCM.

Using the Auro-3D codec, *all audio standards* (Stereo, 5.1 and AURO-3D) can be integrated into just one standard 5.1 PCM stream, which will play back on every 5.1 Surround System. Moreover, one standard 5.1 PCM stream is able to include all past, new and future audio standards: Stereo, Surround 5.1 and AURO-3D (18 channels in total) integrated in the 5.1 Standard PCM stream, which plays back the original 5.1 mix without using a codec. This means that, when a movie is mastered with the Auro-3D codec, anybody who doesn't have an Auro-3D System will still hear the 5.1 tracks in exactly the same quality as they normally would have had in standard 5.1 Surround. But if they have the Auro-3D decoding system, the engine will extract all of the hidden information from that PCM signal and put it back in its original 3D audio format without any audible compromise!

How does it work? It is generally accepted that the dynamic range of a final mix master for end-users does not have to be more than 20-bit (= a dynamic range of about 120 dB). No soundtrack has such an unrealistically high dynamic range – that is, the difference between the loudest and the softest parts of the audio is 120 dB. Classical music is known to have a much higher dynamic range than pop music (which has an average of max. 20 - 30 dB), but the dynamic range of classical music will not be more than the dynamic range of an orchestra, which is never more than 120 dB between the softest and loudest parts of the composition. In fact, the dynamic range of mastered sound (re)-production will rarely exceed 96 dB (slightly more than the dynamic range of a 16-bit compact disc).

In many cases, the dynamic range is compressed during real-time distributions to avoid the dramatic differences in audio level. This form of compression is used in almost every television and radio broadcast facility today.

This is not the case during the workflow (before the final master is made), where it is still important to have 24 bits providing enough headroom for mixing without any compromise. But as soon as the final mix is made, 20-bit PCM masters do have uncompromised perfect audio quality. In fact, during a speech at an ICTA seminar in January 2011, industry veteran Tomlinson Holman explained to the public that 24-bit resolution distribution masters are “overkill”, and he explained why lower bit resolutions (like 16-20 bit) provide an adequate dynamic range to reproduce a film soundtrack accurately.

In summary, the Auro-3D system turns all kinds of incoming sources into a Fully Immersed 3D Sound Experience. Without an Auro-3D system, the 5.1 Surround standard applies, without any noticeable difference in quality. Auro-3D is the only audio technology that is the logical choice for next-generation sound production, distribution and reproduction.

CONCLUSION

From a technical perspective, Auro-3D has many advantages over other new audio technologies. Auro-3D enables single inventory distribution and uses no “lossy” compression system – it simply embeds extra channel information in the least significant bits in a 24-bit audio stream. This innovative and unique approach allows Auro-3D content to be transported using the market’s current standards. Furthermore, it enables mix stage quality with less bandwidth than other lossless data compression techniques. Plus, it does all this with ultra-low latency enabling near to real-time performance – making it the fastest audio decoding technology on the planet.

Advanced mixing and mastering tools are already available: e.g. plug-ins for AMS/Neve consoles and Digidesign / ProTools systems. Compatibility with location / production sound has also been considered: new recorders and microphones for 3D sound are readily available and can be implemented using existing gear. Regarding the in-theater setup: Auro-3D is compatible with today’s auditoriums and mix stage design. Additional speakers and amps to support the Auro-3D format cost a fraction of the investment required for other systems that have been proposed.

Auro-3D is the perfect match for the visual 3D experience, providing the most natural and immersive movie experience imaginable. Being tuned to the needs of theater owners, studios and creative professionals, Auro-3D has the best offer on price, size and quality for the only *real* 3D Sound experience on the market. Representing the next-generation 3D Experience, Auro-3D provides for easy installation above existing surround speakers while maintaining backwards & future compatibility.

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