

Exploring Surround Sound Systems

Human ears receive sound from not for only one direction. From mono and stereo sound not sufficiently reproduce surround sound the realism of perceived sound. It is probably good enough for listening to music from 2.0 stereo or a 5.1 surround sound system, which provide, horizontally, enough information or satisfaction of surrounded sound. However, visual image with sound which is very close to our real life. This article describes the limitations of present surround sound systems and its future direction.

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Reproduction of audio starts with mono has been a single reproduction source. After that it become stereo which has two reproduction sources that is expended left and right horizontally. However, mono and stereo audio reproduction techniques assume that the sound source is coming from the front, like a music stage, but unlike real life. Apart from a musical listening perspective, we cannot assume that sound is coming from front always. For example, if we are in the middle of a war combat situation, sound will come from all directions with different distances and levels. However, mono and stereo audio are not suitable for these kinds of sounds. Additional reproduction sources are required to create the illusion of war combat. When this illusion can be achieved, where the listener feels like they are in the middle of a war, surround sound will then be a big improvement over stereo. However, current 5.1 surround sound systems cannot perfectly reproduce the illusion of sound due to some limitations such as lack of vertical surround information, limited bandwidths of side phantom power image and ignoring early reflections in different rooms. 5.1 and 2.0 sound systems could be enough for music reproduction in which mainly sound coming from front horizontally. Sound on screen, however, which is most close to our real life listening, needs the directionality of the sound field, which is composed of spherical harmonic components, not just horizontally surrounded.

History of Past Surround Sound Systems

The first kind of surround sound is stereo sound, with sound coming from two directions. But, a human's ear is able to distinguish not only sound from two direction, but from almost all directions. This gives birth to advanced kind of surround sound setup. After Bell laboratories invented multi-channel audio formats, including three-channel stereo (left, center and right), Walt Disney engineers developed a technology called Fantasound in 1938. Fantasound stored three channels of audio and a control track on the film itself, with playback through the five channels. The main sound track is only three front channels. The rest of two rear channels were recorded on a separate reel of film. Arguably, this is the very first surround sound system, which attempts to surround the listener with the sounds for the movie "Fantasia". The speaker configuration of this system is very close to today's 5.1 surround sound system. Unfortunately, installing the Fantasound system in cinemas was too expensive to have commercial success. The 1950's Multi-channel Stereo and Early 1970's Quadraphonic sound systems also were unsuccessful due to financial problems.

Commonly Available Surround Sound Setups

• 4.0 Surround Speaker Setup

The basic kind of surround system. It consists of four speakers placed at 90 degrees to the adjacent speaker around the listener. It lacks a subwoofer.

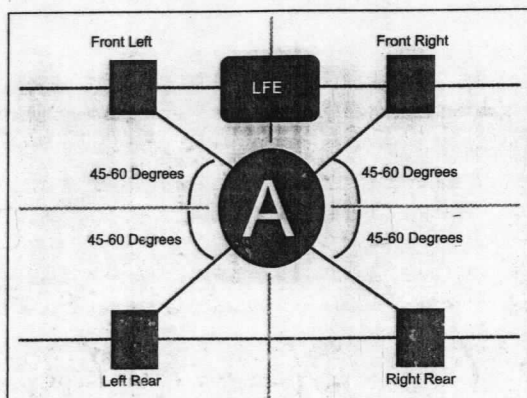


Fig. 1. 4.1 Surround Speaker Setup

• 4.1 Surround Speaker Setup

This one has proper four surround channel in each direction plus a subwoofer (Refer Figure: 1).

• 5.1 Surround Speaker Setup

A very popular and most accepted form of surround system. In this case, there are five surround channels and 1 LFE speaker (subwoofer) (Refer Figure: 2).

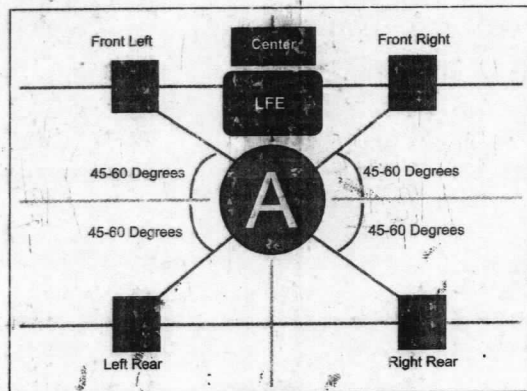


Fig. 2. 5.1 Surround Speaker Setup

• 6.1 Surround Speaker Setup

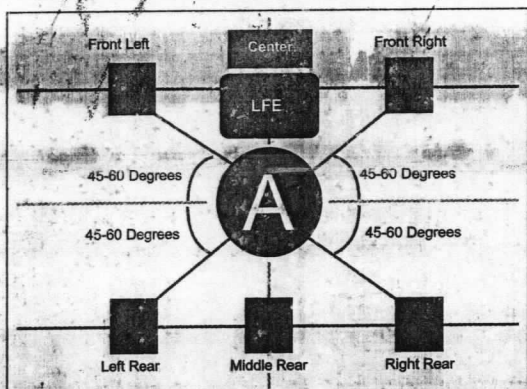


Fig. 3. 6.1 Surround Speaker Setup

This is an extended version of 5.1 surround system, and adds another speaker at the back of the listener (Refer Figure: 3).

• 7.1 Surround Speaker Setup

This set up is similar to the 6.1 surround set up, but an extra speaker has been added for extra realism. Currently, only few computer games support this

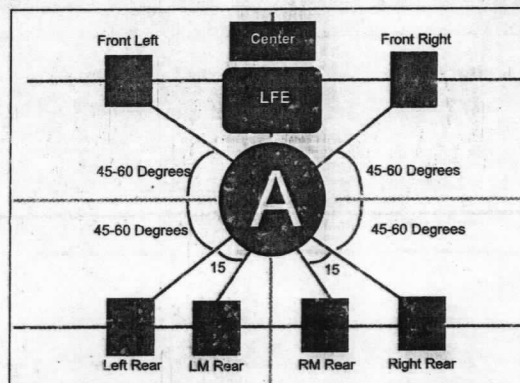


Fig. 4. 7.1 Surround Speaker Setup

format (Refer Figure: 4).

Review Of Today Surround Sound Systems

• Dolby Stereo (analog)

Dolby Stereo or simply Dolby Analog is the original analogue optical technology developed for 35mm prints and is encoded with four audio channels: left, centre, right (which are located behind the screen) and Surround (which is heard from speakers at the sides and to the rear of the theatre) for ambient sound and special effects.

In 1976, Dolby Laboratories introduced Dolby Stereo. Two channels of sound reproduction are not adequate for movie stereo because movie screens are too wide for the left and right channel. A separate center channel and speaker is needed to



Fig. 5. Dolby Stereo Analogue.

localize dialogue for audiences and a surround channel is needed for ambient sound.

These four channels of sound information and movie print are encoded to two physical tracks. (Even today, movie prints with digital soundtracks have Dolby 'analogue' soundtracks to ensure compatible playback in all cinemas).

• Dolby Digital (SR-D)

Dolby Digital (also known as AC-3 and SR-D) delivers digital audio via six clearly separate channels (referred to as "5.1"). The three front channels deliver crisp, clean dialogue and accurate placement of sound, while twin surround channels wrap around the audience and immerse them in the action.

In the late 1980s, Dolby Laboratories undertook the application of digital audio technology to 35mm film sound in response to growing interest from the film industry. In order to retain an

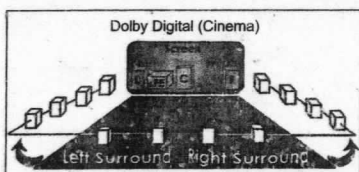


Fig. 6. Dolby Digital playback in the cinema.

analogue track so that release prints could continue to play in any cinema, it was decided that a separate new Dolby Digital optical track be placed. Dolby Digital brings 5.1-channel surround sound into your home. It provides five full-range audio channels: three for speakers at the front and two for surround speakers at the sides. A sixth, low-frequency effects (LFE) channel carries those deep bass sound effects you feel more than hear. Because it covers only about one-tenth of the audible range, the LFE channel is called a ".1" channel. Its low bass sounds

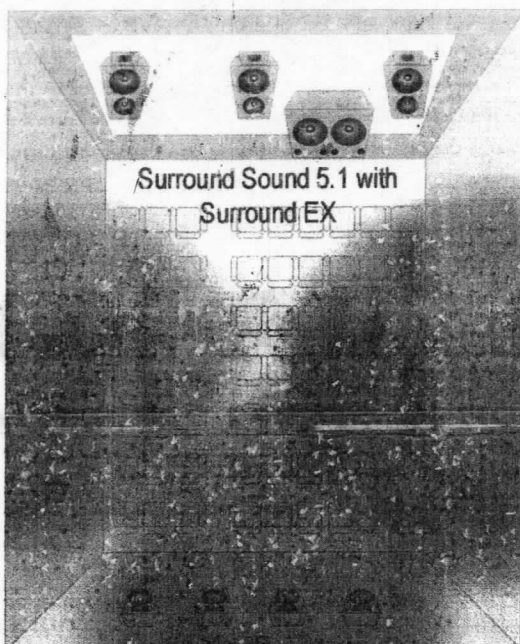


Fig. 7. Surround Sound 5.1 with Surround EX

can be channeled to the subwoofer in the home theater system, if it has one or to any other speakers in the system that can reproduce low bass.

A newer variation of Dolby Digital, called Surround EX, encodes Dolby Digital program material with a third surround channel that can be decoded at the listener's option for playback over additional surround speakers placed behind the viewers (Figure 7). Surround EX program material is fully compatible with regular Dolby Digital 5.1 playback (the additional center rear information is split between the left and right surround channels).

• Digital Theatre System (DTS)

Also known as Digital Theater Systems is a discrete digital 5.1 surround sound format used for movies and music. It is a direct competitor of Dolby Digital 5.1 (DD 5.1), but one advantage of DTS over DD 5.1 is that it has a much higher bitrate than equivalent Dolby tracks. DTS 5.1 typically uses 768-1536 kbit/s (overall), while Dolby 5.1 uses 384-448 kbit/s. In addition to DTS 5.1, there are still more variants known as DTS-ES also known as Digital Theatre System Extended Surround, which puts in support for 6.1 surround sound system. DTS is a multi-channel digital surround format used for both commercial/theatrical and consumer grade application. It is used for movie sound both on film and on DVD, and during the last few years of the format's existence, several laserdisc releases had DTS soundtracks.

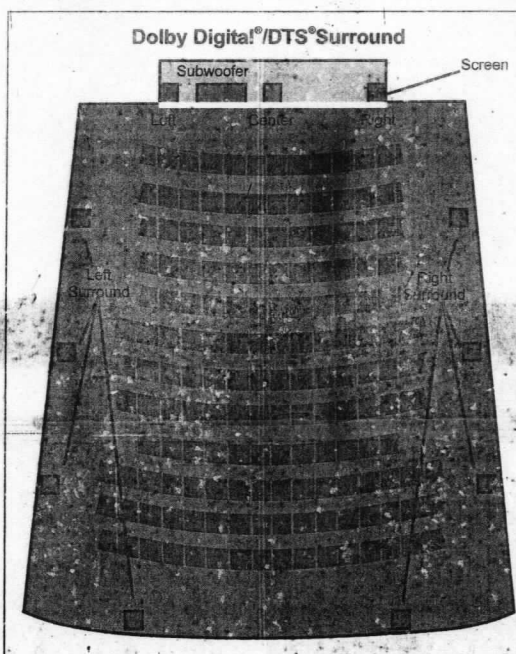


Fig. 8. Dolby Digital / DTS Surround Sound

DTS proponents claim that the extra bits give higher fidelity and more dynamic range, providing a richer and more lifelike sound. A DTS track is often louder with fewer hisses, even at the same relative playback volume.

- **DTS NEO:6**

Neo:6 can take stereo content and convert the sound into 5.1 or 6.1 channel format.

- **DTS 96/24**

Allows the delivery of 5.1 channels of 24-bit, 96 kHz audio and high quality video on the DVD-Video format. Prior to the invention of DTS 96/24, it was only possible to deliver two channels of 24-bit, 96 kHz audio on DVD-Video. DTS 96/24 can also be placed in the video zone on DVD-Audio discs, making these discs playable on all existing DVD players.

- **DTS-HD Master Audio**

Previously known as DTS++ and DTS-HD, DTS-HD Master Audio supports a virtually unlimited number of surround sound channels, can downmix to 5.1- and two-channel, and can deliver audio quality at bit rates extending from DTS Digital Surround up to lossless. Although technically superior over its Dolby counterpart, DTS-HD Master Audio is selected only as an optional surround sound format for Blu-ray and HD-DVD. DTS-HD Master Audio and Dolby TrueHD are the only technologies that deliver compressed lossless surround sound for these new disc formats, ensuring the highest quality audio performance available in the new standards.

- **Dolby Digital Surround EX**

It introduces a center rear channel to the 5.1 playback format of Dolby Digital. It is matrixed out of the rear left and right channels, and so does not create true 6.1 sound.

- **Dolby Digital Plus**

It is an audio codec based on and compatible with Dolby Digital, but more advanced. The DVD Forum has selected Dolby Digital Plus as a standard audio format for HD-DVD video. Dolby Digital Plus can also be applied to limited bandwidth environments such as broadcast television.

- **Dolby TrueHD**

It is Dolby's next generation lossless coding technology. It offers bit-for-bit sound reproduction identical to the studio master. Over seven full-range 24-bit/96kHz discrete channels are supported (plus a LFE channel, making it 7.1 surround) along with the HDMI interface. It has been selected as the mandatory format for HD DVD and as an optional

format for Blu-ray Disc. Theoretically, Dolby True HD can support more channels, but this number has been limited to 8 for HD DVD and Blu-Ray.

- **Dolby Pro Logic / II / IIx**

Dolby Pro Logic is based on a basic Matrix technology. When a Dolby Surround soundtrack is created, four channels of sound are matrix-encoded into an ordinary stereo (two channel) sound track by using phase shift techniques. A Pro Logic decoder/processor "unfolds" the sound into the original 4.0 surround-left and right, center, and a single limited frequency-range mono rear channel-while systems lacking the decoder playback the audio as standard Stereo.

Dolby Pro Logic II also decodes 5.1 channels from stereo signals encoded in traditional four-channel Dolby Surround. DPL II implements greatly enhanced steering compared to DPL, and as a result, offers an exceptionally stable sound field that simulates 5.1 channel surround sound to a much more accurate degree than the original Pro Logic.

Dolby Pro Logic IIx system can take stereo and Dolby Surround source material and up-convert it to 5.1, 6.1, or 7.1 channel surround sound.

- **Sony Dynamic Digital Sound (SDDS)**

SDDS is a cinema sound system developed by Sony. Digital sound information is recorded on both outer edges of the 35mm film release print. The System supports up to 8 independent channels of sound: 5 front channels, 2 surround channels and a sub-bass channels. SDDS Sony Dynamic Digital Sound has the capacity for 8 channels. It is strongly argued that SDDS is the best performing format. The digital data is stored on the outer edges of the film stock. There are some reviews that claim the outer edges are vulnerable to wear and damage, and again there are other reviews that state the opposite. SDDS can provide for 5 screen channels plus independent surrounds and sub bass. It appears SDDS is technically supported but not promoted.

- Dolby 320Kb/s compression ratio 10:1 average 64Kb/s per channel for 5 channels.

- DTS 1.04Mb/s compression ratio 4:1 average 240Kb/s per channel for 5 channels.

- SDDS 2.46 Mb/s compression ratios 5:1 average 307Kb/s per channel for 8 channels, but because SDDS has back up tracks the average may be similar to DTS.

Limitations Of Present Surround Systems

There are three prominent digital surround formats in use today: Dolby SR-D, Digital Theatre System (DTS), and Sony Dynamic Digital Sound (SDDS). Economic rationalizing favored 35 mm and this caused the high cost superior 70 mm films with its 5 screen sound channel to be used less and less.

They are similar in their print master requirements except for the number of channels. In all cases, the 0.1 channels designation refers to a separate low frequency channel with a smaller bandwidth requirement. These Surround systems have some limitations such as side phantom imaging works well only for limited-bandwidth material, because different frequencies image differently on the sides, leading in turn to the break up of sounds panned from front to rear. Also, the 5.1 system does not take into consideration early first reflections, nor does it simulate a sense of height.

The 5.1 Surround system was developed as a minimum number of channels for surround due to distribution and economical reasons. Two channel sound reproduction was easy enough to implement, back in the 1950s, even as filmmakers continued to regard four channels as the minimum amount necessary to create a life like sound-field. Perhaps the weakest point of the current surround system is that it does not simulate the sound of height. It makes it very hard for a sound designer who wants to create the sound image such as the sound effect of an airplane flying over the audience. Considering a minimum amount of channels for future surround sound, two additional front channels (upper left and upper right) are necessary for simulating the sense of height. It is also essential to develop new mixing techniques to localize the sound source on spherical atmospheric sound reproduction systems. New mixing techniques can be used in situations which cannot use sound field sound recordings. The sound designer can record as mono and put or move the sound source anywhere around the spherical surround sound system if the mixing techniques (panning horizontally and vertically, determining the distance of source) were possible. For future surround sound systems more and more additional channels are required to achieve accurate sound source images. However, increasing the channels is not a simple matter. Even the ITU 5.1 surround system is hard to install at home due to the location of furniture and limitations of room size and surface material. Also, high costs make it hard to distribute to consumers. 1940s Fantasound and 1950s quadraphonic

failed due to the high cost of installation. About 99% of current cinema is installed with Dolby Digital, DTS or SDDS 5.1 channel configurations, therefore, future surround sound should be extended from these formats, rather than design completely new systems.

Future Surround Sound System

Present 2.0 and 5.1 reproduction systems have the same principle regarding the creation of phantom sound images between two loudspeakers or 5 loudspeakers. Future formats of surround sound systems also have this principle with more accurate and additional vertical phantom images. Another factor of future surround system could take account of early reflections which can recreate room acoustics. Current 5.1 and 2.0 reproduction systems works differently due to the room acoustic conditions. Also, the number of low frequency effect channels increase to improve the envelopment of surround sound.

• 10.2 Surround Sound System

The 10.2 surround sound format was developed by THX creator Tomlinson Holman of TMH Labs. This is an extended version of the ITU 5.1 System and is actually a 12.2 system that uses a total of 16 loudspeakers. The additional 6 channels can recreate the acoustics of nearly any location with astonishing realism. A weak point of current 5.1 systems is that the system does not take account the early reflections which is normally from reflective ceiling surfaces nor simulates the sound of height. The additional 6 channels can recreate the acoustics of nearly any location with astonishing realism. A weak point of current 5.1 systems is that the system does not take account the early reflections which is normally from reflective ceiling surfaces nor simulates the sound of height. Holman's new system simply fixes this problem with upper left and right channels, which can simulate a sense of height. Also, the placement of two upper speakers (45 degrees above and to the left and right of the audience) is the key that recreates early reflections, which reaches the ear at a slightly different time, allowing the brain to both localize the primary sound and compute the size of the room.

Wide fronts are added to simulate early reflections from the sidewall and by spreading out the sound in the front, clarity is also improved and more possibilities for envelopment are added. Separate side and rear speakers are also added to eliminate

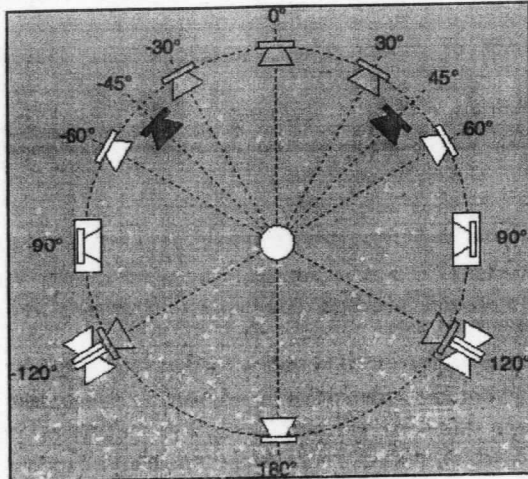


Fig. 10. Extended version of 5.1 systems

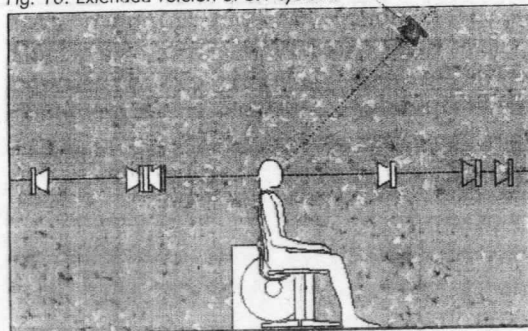


Fig. 11. 45 degrees upper front speaker

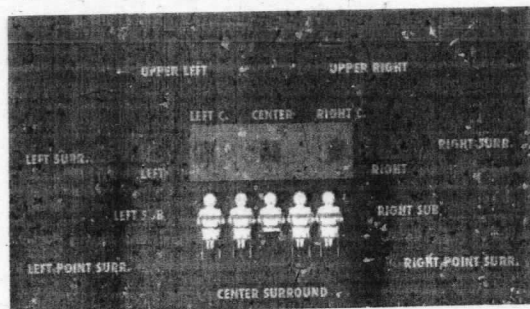


Fig. 12. 10.2 configurations.

the compromise between envelopment and rear imaging along with a rear center channels so that hard rear pans are possible. Finally, two low-frequency channels are added for bass envelopment and improve spatial reproduction. Although low frequencies are not very localizable, it was found that splitting the bass on either side of audience increase the sense of envelopment.

• NHK 22.2 Surround Sound System

NHK has developed a 22.2 multi channel sound system for ultrahigh-definition video. As shown in Figure 13, the 22.2 multichannel sound system has

three layers of loudspeakers: an upper layer of 9 channels, middle layer of 10 channels and lower layer of three channels. The 22.2 multichannel sound system was developed to reproduce an immersive and natural three-dimensional sound field with superior presence and reality. Because of the complicated arrangement of loudspeakers compared with the 5.1 surround sound arrangement, conventional surround sound production equipment is not effective for production using the 22.2 multichannel sound system.

This system can create an even more accurate sound image than 10.2. The three layers of sound system are ideally close to a spherical atmosphere. If new mixing techniques, which can pan up, down, left and right fully support this system, sound

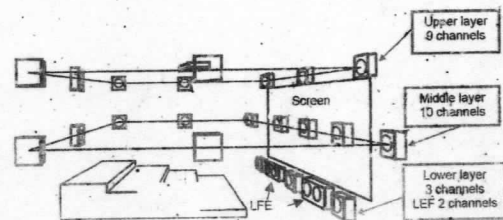


Fig. 13. Three layers of surround sound system

images could move in any location that the sound designer wanted. However, as the channels increase, more time consuming mixing is required because the designer must repeat various operations and also combine different effects for producing such surround sound effects. For the 22.2 multi-channel sound systems, further work is needed on creating vertical movement of a sound image and on creating a three-dimensional sound field.

Conclusion

Increasing the numbers of channels is a very obvious future direction to make it possible to recreate the sense of height and room acoustics. However, more study of surround mixing techniques is required to support new generations of spherical multi dimensional surround systems. The possibilities are almost limitless.

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