

SURROUND SOUND

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Surround sound is a technique for enriching the sound reproduction quality of an audio source with additional audio channels from speakers that surround the listener (surround channels), providing sound from a 360° radius in the horizontal plane (2D) as opposed to "screen channels" (centre, [front] left, and [front] right) originating only from the listener's forward arc.

Surround sound is characterized by a listener location or sweet spot where the audio effects work best, and presents a fixed or forward perspective of the sound field to the listener at this location. The technique enhances the perception of sound spatialization by exploiting sound localization; a listener's ability to identify the location or origin of a detected sound in direction and distance. Typically this is achieved by using multiple discrete audio channels routed to an array of loudspeakers.

There are various surround sound based formats and techniques, varying in reproduction and recording methods along with the number and positioning of additional channels.

Fields of application

Though cinema and soundtracks represent the major uses of surround techniques, its scope of application is broader than that as surround sound permits to create an audio-environment for all sorts of purposes. Multichannel audio techniques may be used to reproduce contents as varied as music, speech, natural or synthetic sounds for cinema, television, broadcasting, or computers. In terms of music content for example, a live performance may use multichannel techniques in the context of an open-air concert, of a musical theatre or for broadcasting; [1] for a film specific techniques are adapted to movie theater, or to home (e.g. home cinema systems) [2][3]. The narrative space is also a content that can be enhanced through multichannel techniques. This applies mainly to cinema narratives, for example the speech of the characters of a film, [4][5][6] but may also be applied to plays for theatre, to a conference, or to integrate voice-based comments in an archeological site or monument. For example, an exhibition may be enhanced with topical ambient sound of water, birds, train or machine noise. Topical natural sounds may also be used in educational applications [7]. Other fields of application include video game consoles, personal computers and other platforms [8][9][10][11]. In such applications, the content would typically be synthetic noise produced by the computer device in interaction with its user. Significant work has also been done using surround sound for enhanced situation awareness in military and public safety applications [12].

Types of media and technologies

Commercial surround sound media include videocassettes, DVDs, and HDTV broadcasts encoded as compressed Dolby Digital and DTS, and lossless audio such as DTS HD Master Audio and Dolby TrueHD on Blu-ray Disc and HD DVD, which are identical to the studio master. Other commercial formats include the competing DVD-Audio (DVD-A) and Super Audio CD (SACD) formats, and MP3 Surround. Cinema 5.1 surround formats include Dolby Digital and DTS. Sony Dynamic Digital Sound (SDDS) is an 8 channel cinema configuration which features 5 independent audio channels across the front with two independent surround channels, and a Low-frequency effects channel. Traditional 7.1 surround speaker configuration introduces two additional rear speakers to the conventional 5.1 arrangement, for a total of four surround channels and three front channels, to create a more 360° sound field.

Most surround sound recordings are created by film production companies or video game producers; however some consumer camcorders have such capability either built-in or available separately. Surround sound technologies can also be used in music to enable new methods of artistic expression. After the failure of quadraphonic audio in the 1970s, multichannel music has slowly been reintroduced since 1999 with the help of SACD and DVD-Audio formats. Some AV receivers, stereophonic systems, and computer soundcards contain integral digital signal processors and/or digital audio processors to simulate surround sound from a stereophonic source.

In 1967, the rock group Pink Floyd performed the first-ever surround sound concert at "Games for May", a lavish affair at London's Queen Elizabeth Hall where the band debuted its custom-made quadraphonic speaker system [13]. The control device they had made, the Azimuth Co-ordinator, is now displayed at London's Victoria and Albert Museum, as part of their Theatre Collections gallery [14].

History

The first documented use of surround sound was in 1940, for the Disney studio's animated film *Fantasia*. Walt Disney was inspired by Rimsky Korsakov's operatic piece, *Flight of the Bumblebee* to have a bumblebee featured in his musical *Fantasia* and also sound as if it was flying in all parts of the theatre – the unsuccessful experimentation led to the music being excluded from the film and the eventual invention of "surround sound"[15][16].

The initial multichannel audio application was called 'Fantasound', comprising three audio channels and speakers. The sound was diffused throughout the cinema, initially by an engineer using some 54 loudspeakers. The surround sound was achieved using the sum and the difference of the phase of the sound. In the 1950s, the German composer Karlheinz Stockhausen experimented with and produced ground-breaking electronic compositions such as *Gesang der Jünglinge* and *Kontakte*, the latter using fully discrete and rotating quadraphonic sounds generated with industrial electronic equipment in Herbert Eimert's studio at the Westdeutscher Rundfunk (WDR). Edgar Varese's

Poeme Electronique, created for the Iannis Xenakis designed Philips Pavilion at the 1958 Brussels World's Fair, also utilised spatial audio with 425 loudspeakers used to move sound throughout the pavilion. There are also many other composers that created ground-breaking surround sound works in the same time period.

In 1978, a concept devised by Max Bell for Dolby Laboratories called "split surround" was tested with the movie "Superman (film)". This led to the 70mm stereo surround release of "Apocalypse Now," which became the first formal release in cinemas with 3 channels in the front and 2 in the rear. The "Apocalypse Now" encoder/decoder was designed by Michael Karagosian, also for Dolby Laboratories. The surround mix was produced by an Oscar-winning crew led by Walter Murch for American Zoetrope. The format was also deployed in 1982 with the stereo surround release of Blade Runner.

5.1 surround sound originated in 1987 at the famous French Cabaret Moulin Rouge. A French engineer, Dominique Bertrand used a mixing board specially designed in cooperation with Solid State Logic, based on 5000 series and including 6 channels. Respectively: A left, B right, C centre, D left rear, E right rear, F bass. The same engineer had already achieved a 3.1 system in 1974, for the International Summit of Francophone States in Dakar Senegal.

Creating surround sound

Surround sound is created in several ways. The first and simplest method is using a surround sound recording technique—capturing two distinct stereo images, one for the front and one for the back or by using a dedicated setup, e.g. an augmented DECCA Tree [17], the OCT (Optimized Cardioid Triangle) or XYtri [18] configuration—and/or mixing-in surround sound for playback on an audio system using speakers encircling the listener to play audio from different directions. A second approach is processing the audio with psychoacoustic sound localization methods to simulate a two-dimensional (2-D) sound field with headphones. A third approach, based on Huygens' principle, attempts reconstructing the recorded sound field wave fronts within the listening space; an "audio hologram" form. One form, wave field synthesis (WFS), produces a sound field with an even error field over the entire area. Commercial WFS systems, currently marketed by companies Sonic Emotion and Iosono, require many loudspeakers and significant computing power.

The Ambisonics form, also based on Huygens' principle, gives an exact sound reconstruction at the central point; less accurate away from center point. There are many free and commercial software programs available for Ambisonics, which dominates most of the consumer market, especially musicians using electronic and computer music. Moreover, Ambisonics products are the standard in surround sound hardware sold by Meridian Audio, Ltd. In its simplest form, Ambisonics consumes few resources, however this is not true for recent developments, such as Near Field Compensated Higher Order Ambisonics [19]. Some years ago it was shown that, in the limit, WFS and Ambisonics converge [20]

Finally, surround sound can also be achieved by mastering level, from stereophonic sources as with Penteo, which uses Digital Signal Processing analysis of a stereo recording to parse out individual sounds to component panorama positions, then positions them, accordingly, into a five-channel field. However, there are more ways to create surround sound out of stereo, for instance with routines based on the QS and SQ Quad routines, where instruments were divided over 4 speakers in the studio. This way of creating surround with software routines is normally referred to as "upmixing"[21].

Mapping channels to speakers

In most cases, surround sound systems rely on the mapping of each source channel to its own loudspeaker. Matrix systems recover the number and content of the source channels and apply them to their respective loudspeakers. With discrete surround sound, the transmission medium allows for (at least) the same number of channels of source and destination; however, one-to-one, channel-to-speaker, mapping is not the only way of transmitting surround sound signals.

The transmitted signal might encode the information (defining the original sound field) to a greater or lesser extent; the surround sound information is rendered for replay by a decoder generating the number and configuration of loudspeaker feeds for the number of speakers available for replay – one renders a sound field as produced by a set of speakers, analogously to rendering in computer graphics. This "replay device independent" encoding is analogous to encoding and decoding an Adobe PostScript file, where the file describes the page, and is rendered per the output device's resolution capacity. The Ambisonics and WFS systems use audio rendering; the Meridian Lossless Packing contains elements of this capability.

Bass management

Surround replay systems may make use of bass management, the fundamental principle of which is that bass content in the incoming signal, irrespective of channel, should be directed only to loudspeakers capable of handling it, whether the latter are the main system loudspeakers or one or more special low-frequency speakers called subwoofers.

There is a notation difference before and after the bass management system. Before the bass management system there is a Low Frequency Effects (LFE) channel. After the bass management system there is a subwoofer signal. A common misunderstanding is the belief that the LFE channel is the "subwoofer channel". The bass management system may direct bass to one or more subwoofers (if present) from any channel, not just from the LFE channel. Also, if there is no subwoofer speaker present then the bass management system can direct the LFE channel to one or more of the main speakers.

Low Frequency Effects (LFE) channel

Because the low-frequency effects channel requires only a fraction of the bandwidth of the other audio channels, it is referred to as the ".1" channel; for example "5.1" or "7.1".

The LFE is a source of some confusion in surround sound. The LFE channel was originally developed to carry extremely low "sub-bass" cinematic sound effects (with commercial subwoofers sometimes going down to 30 Hz, e.g., the loud rumble of thunder or explosions) on their own channel. This allowed theaters to control the volume of these effects to suit the particular cinema's acoustic environment and sound reproduction system. Independent control of the sub-bass effects also reduced the problem of intermodulation distortion in analog movie sound reproduction.

In the original movie theater implementation, the LFE was a separate channel fed to one or more subwoofers. Home replay systems, however, may not have a separate subwoofer, so modern home surround decoders and systems often include a bass management system that allows bass on any channel (main or LFE) to be fed only to the loudspeakers that can handle low-frequency signals. The salient point here is that the LFE channel is not the "subwoofer channel"; there may be no subwoofer and, if there is, it may be handling a good deal more than effects [22].

Some record labels such as Telarc and Chesky have argued that LFE channels are not needed in a modern digital multichannel entertainment system. They argue that all available channels have a full frequency range and, as such, there is no need for an LFE in surround music production, because all the frequencies are available in all the main channels. These labels sometimes use the LFE channel to carry a height channel, underlining its redundancy for its original purpose. The label BIS generally uses a 5.0 channel mix.

Surround sound specifications

The descriptions of surround sound specifications below distinguish between the number of discrete channels encoded in the original signal and the number of channels reproduced for playback. The number of channels reproduced for playback can be changed by using matrix decoding. A distinction is also made between the number of channels reproduced for playback and the number of speakers used to reproduce (each channel may refer to a group of speakers). The graphics to the right of each specification description represent the number of channels, not the number of speakers.

Notation

This notation, "5.1", reflects the number of full range channels; including a ".1" to reflect the limited range of the LFE channel.

E.g. 1 basic stereo speakers with no LFE channel = 2.0; 5 full-range channels + 1 LFE channel = 5.1

It can also be expressed as the number of full-range channels in front of the listener, separated by a slash from the number of full-range channels beside or behind the listener, separated by a decimal point from the number of limited-range LFE channels.

E.g. 2 front channels + 2 side channels + an LFE channel = 3/2.1

This notation can then be expanded to include the notation of Matrix Decoders. Dolby Digital EX, for example, has a sixth full-range channel incorporated into the two rear channels with a matrix. This would be expressed:

E.g. 3 front channels + 2 rear channels + 3 channels reproduced in the rear in total + 1 LFE channel = 3/2:3.1

Note: The term stereo, although popularized in reference to two channel audio, can also be properly used to refer to surround sound, as it strictly means "solid" (actually meaning 3 dimensional sound) sound. However this is no longer a common usage and "stereo sound" is almost exclusively used to describe two channels, left and right, sound.

Channel identification

In accordance with ANSI/CEA-863-A [23]

Zero-based order within multi-channel mp3/wav/flac datastream ^{[24][25][26][27]} ⇄	Order within DTS/AAC ^{[28][29]} ⇄	Channel name ⇄	Color-coding on commercial receiver and cabling ⇄
0	1	Front left	White
1	2	Front right	Red
2	0	Center	Green
3	5	Low frequency	Purple
4	3	Surround left	Blue
5	4	Surround right	Grey
6	6	Surround back left	Brown
7	7	Surround back right	Khaki

Front left	Center	Front right
Surround left		Surround right
Surround back left		Surround back right
Low frequency		

Sonic Whole Overhead Sound

In 2002, Dolby premiered a master of We Were Soldiers which featured a Sonic Whole Overhead Sound soundtrack. This mix included a new ceiling-mounted height channel.

Ambisonics

Ambisonics is a series of recording and replay techniques using multichannel mixing technology that can be used live or in the studio and which recreates

the soundfield as it existed in the space, in contrast to traditional surround systems, which can only create illusion of the soundfield if the listener is located in a very narrow sweetspot between speakers. Any number of speakers in any physical arrangement can be used to recreate a sound field. With 6 or more speakers arranged around a listener, a 3-dimensional ("periphonic", or full-sphere) sound field can be presented. Ambisonics was invented by Michael Gerzon.

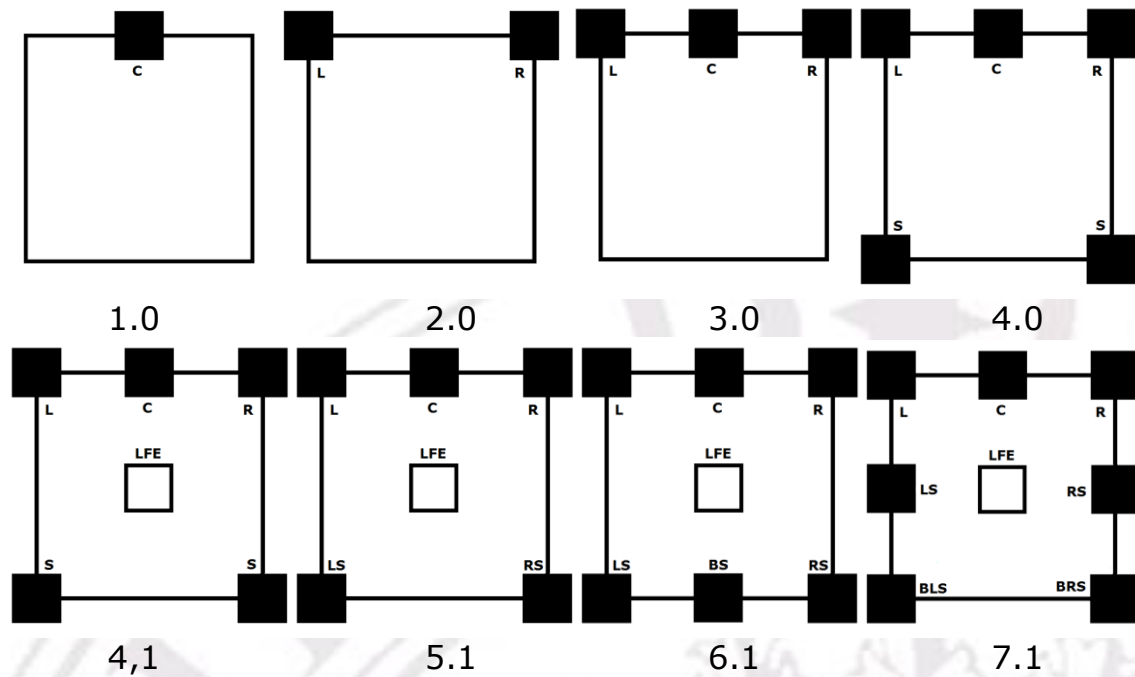
Panor-Ambiophonic (PanAmbio) 4.0/4.1

PanAmbio combines a stereo dipole and crosstalk cancellation in front and a second set behind the listener (total of four speakers) for 360° 2D surround reproduction. Four channel recordings, especially those containing binaural cues, create speaker-binaural surround sound. 5.1 channel recordings, including movie DVDs, are compatible by mixing C-channel content to the front speaker pair. 6.1 can be played by mixing SC to the back pair.

Standard speaker channels

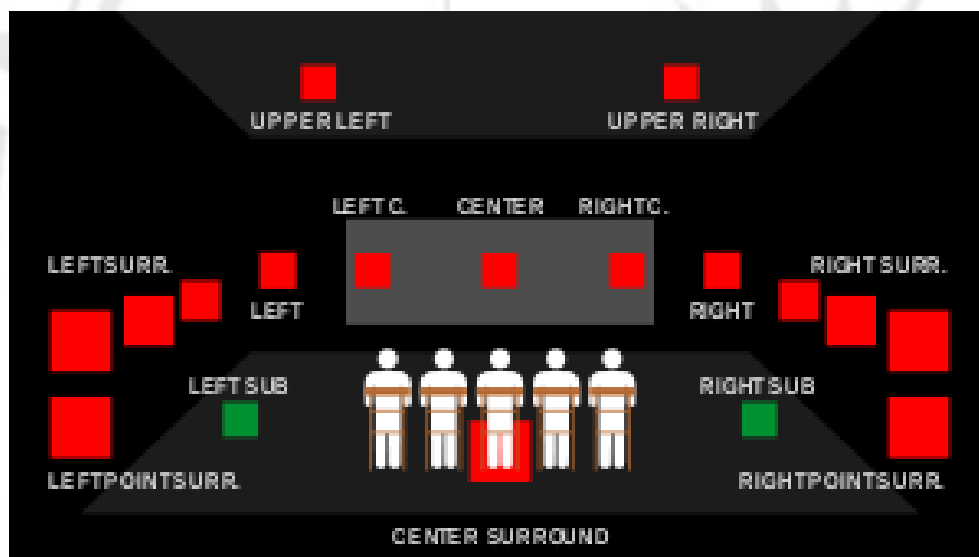
This table shows the various speaker configurations that are commonly used for end-user equipment. The order and identifiers are those specified for the channel mask in the standard uncompressed WAV file format (which contains a raw multichannel PCM stream) and are used according to the same specification for most PC connectible digital sound hardware and PC operating systems capable of handling multiple channels.[30][31] While it is certainly possible to build any speaker configuration, there isn't a lot of commercially available movie or music content for alternative speaker configurations. Such cases, however, can be worked around by remixing the source content channels to the speaker channels using a matrix table specifying how much of each content channel is played through each speaker channel.

Channel name	Identifier	Index	Flag	1.0 Mono <small>[Note 1]</small>	2.0 Stereo <small>[Note 2]</small>	3.0 Stereo	3.0 Surround	4.0 Quad	4.0 Surround	5.0 <small>[Note 3]</small>	5.0 Side <small>[Note 3]</small>	6.0	6.0 Side <small>[Note 3]</small>	7.0
Front Left	SPEAKER_FRONT_LEFT	0	0x00000001	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Front Right	SPEAKER_FRONT_RIGHT	1	0x00000002	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Front Center	SPEAKER_FRONT_CENTER	2	0x00000004	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Back Left	SPEAKER_BACK_LEFT	4	0x00000010	No	No	No	No	Yes	No	Yes	No	Yes	No	Yes
Back Right	SPEAKER_BACK_RIGHT	5	0x00000020	No	No	No	No	Yes	No	Yes	No	Yes	No	Yes
Front Left of Center	SPEAKER_FRONT_LEFT_OF_CENTER	6	0x00000040	No	No	No	No	No	No	No	No	No	No	Yes
Front Right of Center	SPEAKER_FRONT_RIGHT_OF_CENTER	7	0x00000080	No	No	No	No	No	No	No	No	No	No	Yes
Back Center	SPEAKER_BACK_CENTER	8	0x00000100	No	No	No	Yes	No	Yes	No	No	Yes	Yes	No
Side Left	SPEAKER_SIDE_LEFT	9	0x00000200	No	No	No	No	No	No	No	Yes	No	Yes	No
Side Right	SPEAKER_SIDE_RIGHT	10	0x00000400	No	No	No	No	No	No	No	Yes	No	Yes	No
Front Left Height	SPEAKER_LEFT_HEIGHT	12	0x00001000	No	No	No	No	No	No	No	No	No	No	No
Front Right Height	SPEAKER_RIGHT_HEIGHT	14	0x00004000	No	No	No	No	No	No	No	No	No	No	No



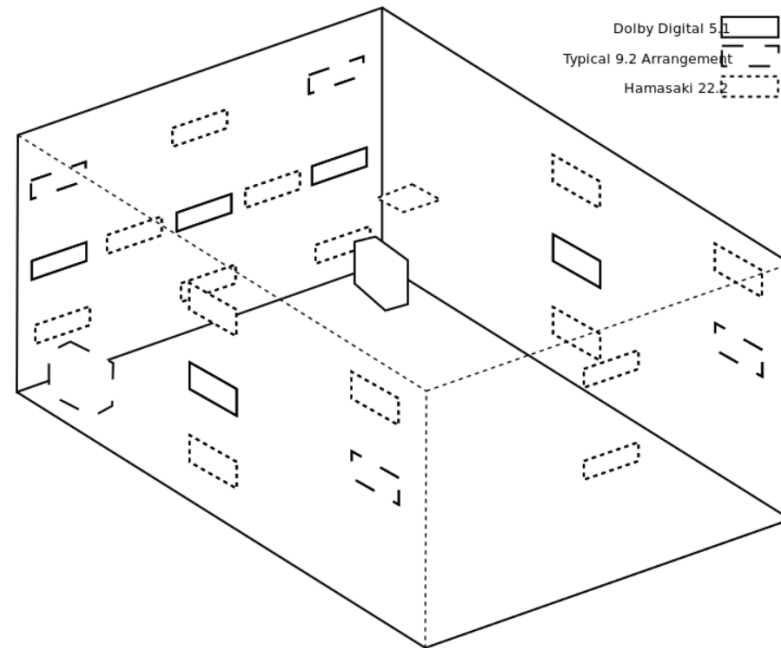
10.2 surround sound

10.2 is the surround sound format developed by THX creator Tomlinson Holman of TMH Labs and University of Southern California (schools of Cinema/Television and Engineering). Developed along with Chris Kyriakakis of the USC Viterbi School of Engineering, 10.2 refers to the format's promotional slogan: "Twice as good as 5.1". Advocates of 10.2 argue that it is the audio equivalent of IMAX.



22.2 surround sound

22.2 is the surround sound component of Ultra High Definition Television, and has been developed by NHK Science & Technical Research Laboratories. As its name suggests, it uses 24 speakers. These are arranged in three layers: A middle layer of ten speakers, an upper layer of nine speakers, and a lower layer of three speakers and two sub-woofers. The system was demonstrated at Expo 2005, Aichi, Japan, the NAB Shows 2006 and 2009, Las Vegas, and the IBC trade shows 2006 and 2008, Amsterdam, Netherlands.



Notes

- Note 1: For historical reasons, when using (1.0) mono sound, often in technical implementations the first (left) channel is used, instead of the center speaker channel, in many other cases when playing back multichannel content on a device with a mono speaker configuration all channels are downmixed into one channel. The way standard mono and stereo plugs used for common audio devices are designed ensures this as well.
- Note 2: Stereo (2.0) is still the most common format for music, as most computers, television sets and portable audio players only feature two speakers, and the red book Audio CD standard used for retail distribution of music only allows for 2 channels. A 2.1 speaker set does generally not have a separate physical channel for the low frequency effects, as the speaker set downmixes the low frequency components of the two stereo channels into one channel for the subwoofer.

- Note 3: a b c THX 5.1 Surround Sound Speaker set-up. This is the correct speaker placement for 5.0/6.0/7.0 channel sound reproduction for Dolby and Digital Theater Systems.
- Note 4: "Sony Print Master Guidelines" This plus an LFE is the correct speaker placement for 8-track Sony Dynamic Digital Sound.

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