Digital Broadcasting with MPEG Surround

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MPEG Surround provides a highly efficient and backwards compatible extension method for the seamless transition to multichannel audio in various broadcasting systems, and is already part of many European and global industry standards. Offering high-quality surround sound at stereo bitrates, MPEG Surrounds avoids the simulcast of stereo and surround audio and therefore enables 5.1 audio even in bandwidth-limited broadcast services.

Appealing to an economically-relevant consumer base, MPEG Surround is the only codec to facilitate mobile multichannel broadcasting, as well as surround music streaming and downloading services. Exciting new opportunities await and, thanks to the ISO MPEG Surround standard, the technology to realise them is now in place.

Despite the fact that broadcasting services have evolved in several significant ways during recent years, many consumers still perceive a gap between the traditional 2-channel stereo transmission and the surround audio experience.

Since the success of mp3, compressed audio for stereo material has become ubiquitous for almost all digital devices and services. When disk-space was still expensive, stereo audio compression enabled efficient storage for personal music libraries, as well as new broadcasting systems and device categories. In a parallel development, the world of surround audio has historically been driven primarily by physical media formats such as DVD, SACD and Blu-ray. The success of cable and satellite TV broadcasting has also been an important contributory factor in this regard.

Established methods for transmitting or compressing surround sound are either discrete or matrix systems. The former has the problem of high bitrates, while the latter involves a poor quality signal on the receiving side. MPEG Surround offers a third way, enabling the realisation of a single distribution format for both high-quality stereo and surround audio that can be optimally presented by mobile devices, digital radio car receivers and in the living room.

The feature-set of MPEG Surround includes:

- generic extension to existing audio coding schemes;
- high-quality multichannel audio reproduction at stereo bitrates;
- full backward compatibility to stereo devices;
- the ability to present surround sound over surround loudspeakers and conventional stereo headphones;

Only one audio codec, the ISO MPEG Surround standard, is capable of providing all of these features.

MPEG Surround basics

MPEG Surround takes the multichannel (e.g. 5.1 channel) input signal and creates a stereo (or mono) downmix. Alternatively, an externally-created downmix signal ("artistic downmix") may be used. This downmix is passed to a conventional audio codec – for example, AAC, HE-AAC or MPEG Layer 2 – which encodes the "core" stereo bitstream.

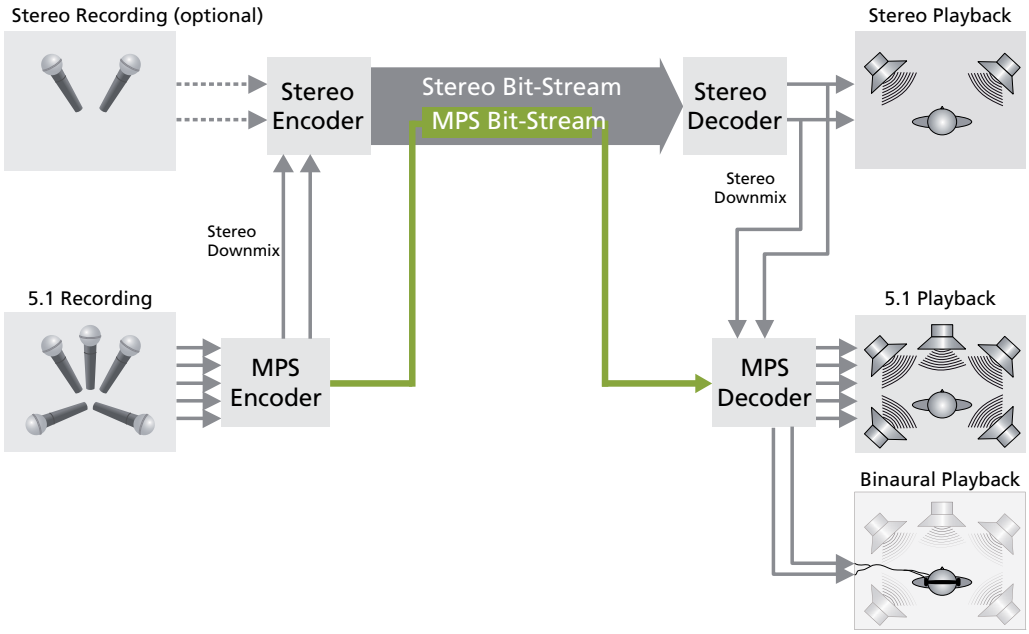

Figure 1
MPEG Surround architecture

The multichannel input signal is analyzed and spatial parameters are derived. Starting at around 4 kbit/s, these parameters are coded extremely efficiently and are transparently embedded into the stereo bitstream as ancillary data.

On the receiving side, a legacy decoder disregards the side information and plays back the stereo downmix. An MPEG Surround-enabled decoder expands the transmitted downmix signal into a multichannel output, based on the side information.

Broadcast applications

Bitrate-efficient surround encoding is essential for digital broadcasting systems in order to enable the seamless transition of existing stereo distribution channels with strict bandwidth constraints towards multichannel audio.

MPEG Surround key features

- Very low bit-rate representation of high-quality, multichannel signals;
- Fully compatible to mono or stereo infrastructure;
- Artistic downmix option to represent the original stereo downmix;
- Surround quality similar to discrete systems at substantially lower bit-rates and superior to matrix-based systems;
- Surround enhancement data rate scalable from 4 kbps up to 32 kbps and beyond to address different application scenarios.

MPEG Surround enables broadcasters to offer stereo and multichannel in one single stream at a data rate comparable to a stereo-only transmission. All legacy devices continue to play back the programme in the usual mono or stereo quality; new receivers play back the same signal in multichannel sound. MPEG Surround is the only codec that enables broadcasters to offer multichannel audio on bandwidth-restricted systems where sufficient bitrate for the simulcast of stereo and multichannel programs is unavailable.

Hence, with MPEG Surround, broadcasters can provide high-quality multichannel audio not only via DVB-S but also via terrestrial broadcasting for stationary or mobile reception, e.g. into cars. Vehicle manufacturers have considerable interest in the introduction of multichannel audio broadcast services for use with the surround playback systems that are pre-installed in many current models. Cars represent a good listening environment for high-quality audio because the environment is fully controlled and the listening positions are well-known. Studies have shown that many drivers are using their cars for at least one hour per day. In this spirit, the car industry has supported many DAB Surround demos.

Figure 2
DAB Surround broadcasting presented at IFA 2007

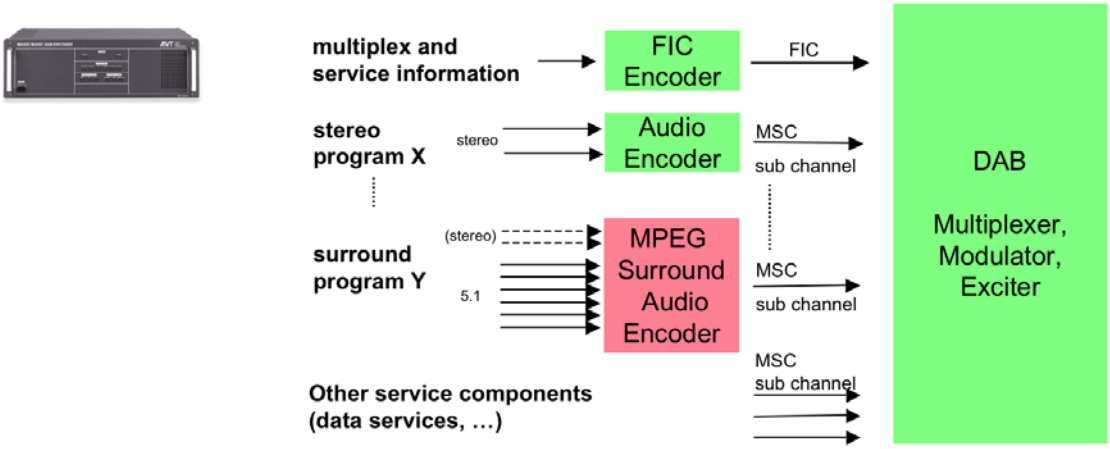

Figure 3
DAB Surround broadcast system

Furthermore, broadcasters can integrate MPEG Surround easily and cost-effectively into their existing broadcast systems – they need only extend the audio encoder with MPEG Surround. Other parts of the broadcast system such as multiplex configuration or additional service components are not affected by this modification. Even the transmission costs remain the same because the overall bitrate of the multichannel service is similar to a stereo-only service.

Industry standards

MPEG Surround is part of several internationally-recognized digital broadcasting, mobile TV and IPTV standards – including WorldDMB (DAB, DAB+, DMB including DMB radio), DRM (DRM30 and

DRM+), DVB (DVB-T, DVB-H) and ATIS-IIF. It is also under consideration as a standard for mobile multimedia services in 3GPP, and the Japanese ISDB-Tsb/mm systems.

Terrestrial Digital Radio – WorldDMB, DRM

Terrestrial Digital Radio in Europe is based primarily on the WorldDMB standard, which includes DAB, DAB+ and DMB.

The DRM (Digital Radio Mondiale) system was developed for frequencies below 30 MHz, and the standard was recently extended to frequencies up to 174 MHz. This extension makes DRM not only a candidate for the digitization of the analogue FM band, but also enables other bands around the FM band to be used for digital radio where it is applicable.

All terrestrial Digital Radio systems have very strict bandwidth limitations, which makes it impossible to use a simulcast of stereo and 5.1 audio as separate streams. Only MPEG Surround can enable multichannel audio in these systems based on the already-deployed stereo audio coding schemes *(Table 1)*.

Table 1
Audio codecs in use in digital radio systems

DAB	MPEG Layer-2
DAB+	HE-AACv2 (framelength 960)
DMB, DMB radio	HE-AACv2 (framelength 1024)
DRM30, DRM+	HE-AACv2 (framelength 960)

For DAB Surround based on MPEG Layer-2, a total subchannel bitrate of 192 kbit/s for stereo and surround is recommended. Other digital radio standards, based on HE-AACv2 for their stereo programme, can operate at lower bitrates, offering surround audio at bitrates as low as 48 kbit/s. In DAB+, for example, a subchannel bitrate of 96 kbit/s can be expected to be sufficient; similar audio bitrates are used for DRM+.

In earlier broadcast trials with MPEG Surround, DAB (MPEG Layer-2) has been used frequently as the typical “enabler” for Digital Radio in Surround Sound. Private Bavarian broadcaster “Rock Antenne” was the first to go on-air 24/7 with MPEG Surround in October 2007. In addition, public broadcaster “Bayerischer Rundfunk” is testing DAB Surround intensively on its “Bayern-4 Klassik” programme. Both programmes employ an audio subchannel capacity of 192 kbit/s.

The most recent presentation of MPEG Surround broadcasting via DRM+ was undertaken in Paris on July 17th 2009 by Syndicat National des Radios Libres (SNRL). Event participants had the opportunity to experience live DRM+ reception with 5.1 surround sound in a car whilst driving.

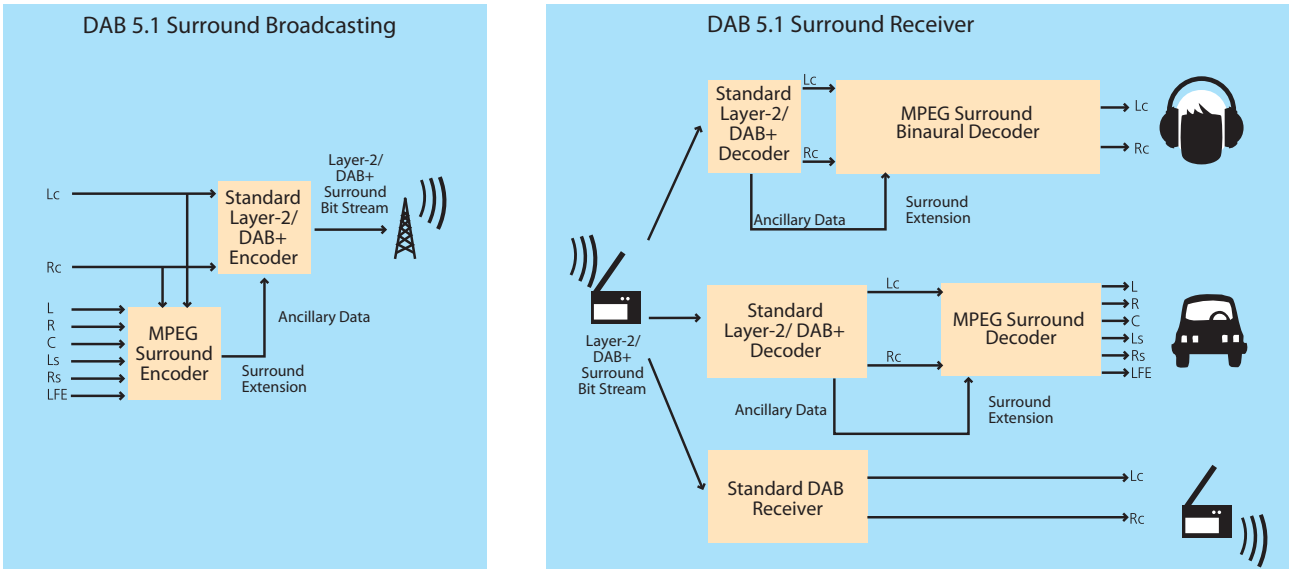

Figure 4
DAB Surround broadcasting architecture

Accompanying Internet Radio streaming services

For those broadcasters and service providers prepared to go "the extra mile", there is also the opportunity to implement surround Internet radio. The use of MPEG Surround enables radio stations to stream true 5.1 surround sound at bitrates as low as 48 kbit/s. Again, these services are backwards compatible to stereo devices, ensuring that listeners yet to upgrade to the latest surround systems are not excluded. The codec's ability to render surround sound virtually on common stereo headphones allows consumers to enjoy a multichannel audio experience on their iPhones or other mobile devices – wherever they may be.

Surround Internet radio – stationary or mobile – constitutes a new technological world, and any trepidation felt by broadcasters and their partners at its arrival is entirely understandable. However, there is no need for a cut-and-dried scenario of the versatile ways of bringing surround sound radio to listeners. Most traditional radio broadcasters will offer Internet radio services as a supplement to their existing broadcasts.

Digital TV Broadcast – Terrestrial, IPTV, Internet TV

Bitrate efficiency and backwards compatibility to stereo are also very important for audio-visual broadcasting and streaming applications. MPEG Surround enables the enhancement of systems to provide multichannel audio, even if the bandwidth for the service is restricted. In such scenarios, the simulcast of stereo and multichannel audio requires a significant amount of the available total bitrate.

DVB-T

MPEG Surround enables a seamless upgrade of existing DVB-T deployments from stereo to multichannel, without negative impact on the visual quality of the service and without the need to reduce the number of services per multiplex.

Today, established DVB-T deployments in many countries employ MPEG Layer-2 stereo audio. An efficient upgrade to multichannel can be enabled by the combination of MPEG Surround with MPEG Layer-2, similar to DAB Surround. For example, a service in SD quality broadcast at 2.5 Mbit/s total bitrate, featuring a simulcast of Layer-2 stereo audio at 192 kbit/s and Dolby AC-3 multichannel at 384 kbit/s, offers only 1.9 Mbit/s for the video encoding resulting in an inferior visual experience for the consumer. MPEG Surround based on Layer-2 uses only 192 kbit/s for the audio component, leaving 2. 3 Mbit/s for video encoding. A difference of almost 25% in video bitrate can make a significant difference to subjective visual quality.

IPTV

IPTV is a TV service provided by telecom operators inside their networks, using multicast distribution on top of the IP connection. It is usually bundled with Internet connectivity and telephony ("triple

Abbreviations

3GPP	3rd Generation Partnership Project	**DRM**	Digital Radio Mondiale
AAC	Advanced Audio Coding	**DSL**	Digital Subscriber Line
AC-3	Dolby Audio Codec 3, also known as Dolby Digital	**DVB**	Digital Video Broadcasting
AVC	Advanced Video Coding (also known as H.264)	**HE-AAC**	High Efficiency AAC
ATIS-IIF	Alliance for Telecommunications Industry Solutions - IPTV Interoperability Forum	**HRTF**	Head-related Transfer Functions
BRIR	Binaural Room Impulse responses	**IPTV**	Internet Protocol Television
DAB	Digital Audio Broadcasting	**ISDB**	Integrated Services Digital Broadcasting
DMB	Digital Multimedia Broadcasting	**L2**	MPEG Layer-2
DPL2	Dolby Prologic II	**MPEG**	Motion Picture Experts Group
		MPS	MPEG Surround
		QoS	Quality of Service

play"), but the IPTV service itself is only available inside the operator's network, not on the open Internet. Because of the "walled-garden" network, the operator can guarantee Quality of Service (QoS) for the IPTV delivery. However, the service offering itself (SD, HD, number of parallel streams, etc.) is determined by the bandwidth available on the "last-mile" to the consumer (e.g. DSL).

MPEG Surround enables multichannel audio and SD-quality video at a total bitrate of only 1.5 Mbit/s, using AVC video coding and HE-AAC stereo audio coding. As a result, multichannel audio services become possible with any DSL connection that offers 2 Mbit/s or more.

If more than one receiver is available in a connected home, it is preferable to have stereo and multichannel audio in one stream. In a mixed assortment of stereo and multichannel IPTV devices that share the same DSL connection, every device can extract the audio component that it requires.

Internet/Web TV

PCs are the main client platform today for Internet and Web TV applications such as catch-up TV services from broadcasters, streaming video portals from content providers, or aggregators and video on-demand services. There is also a clear trend towards network-enabled CE devices such as DTVs to access these services.

Most Internet video services are stereo-only today, mainly because of limited available bandwidth. This also explains why many deployed streaming services still offer a video quality notably below that available with broadcast services; adding surround audio with bandwidth-demanding audio formats such as Dolby AC-3 is not an option. However, some services can already achieve a fairly good video quality using total bitrates of 1 to 1.5 Mbit/s. Thanks to MPEG Surround, these services can be enhanced to stereo-compatible multichannel audio.

On the PC platform, a number of codecs and formats are already in use, although there is a trend towards AVC/HE-AAC and Flash for streaming applications. This is not a problem because the PC's open software architecture allows software updates and easy installation of new codecs or player applications. However, CE devices have different codec requirements and are usually more difficult to upgrade. Consequently, content distributors who wish to target several platforms such as PCs, set-top boxes and/or streaming clients need to encode and stream their content in various formats in parallel. Consolidation of HE-AAC with MPEG Surround considerably reduces the number of encodings per content stream and helps to cut related expenses.

MPEG Surround features

Technical principle

MPEG Surround's compression efficiency is based on the human's spatial perception of auditory sound events. While traditional perceptual audio codecs control their irrelevancy reduction, primarily with regard to monaural and stereophonic perception rules, MPEG Surround makes use of the fact that the listener's spatial perception can be described very efficiently in a parametric way by transmitting important spatial perceptual cues such as channel-level information, phase information and correlation between channels.

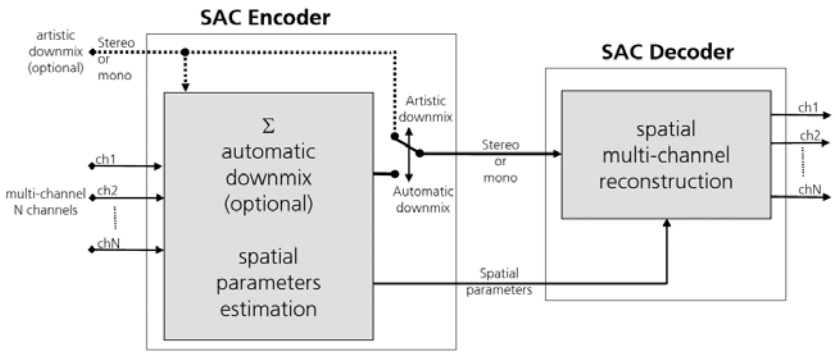

Figure 5
The Principle of Spatial Audio Coding (SAC), which is the basis of MPEG Surround

Bitrates

The accuracy of the spatial parameters, i.e. the bitrate overhead for transmitting surround information on top of the "core" signal, is scalable to a large extent, depending on the available overall bitrate and the application. Even in the highest compression mode that requires only 4 kbit/s for capturing the full spatial image of a 5.1 channel input, the performance of MPEG Surround is clearly superior to conventional matrix-based surround schemes, for instance Dolby Prologic II [9]. These systems generate an entirely estimated surround image based on the phase properties of the downmix signal.

An MPEG Surround encoder can be configured to realise more accurate representation in terms of time and frequency resolution, as well as quantization of the spatial parameters. Moreover, a technique called "residual coding" enables a smooth transition between parametric- and waveform-matched representation.

The additional data rate for the parameters can be increased to use 100 kbit/s or more to achieve a quality comparable to state-of-the-art discrete multichannel codecs, while maintaining full backwards compatibility with stereo receivers.

The rate-distortion curve of an MPEG Surround system when combined with different core codecs is depicted in *Fig. 6*. As reference conditions, discrete 5.1 channel codecs like MPEG-4 HE-AAC and AAC-LC are given. As an example of a matrix-based up-mix, a combination of MPEG Layer-2 and Dolby Prologic II is shown. The bitrate axis relates to the total bitrate (core coder + MPEG Surround parameter rate).

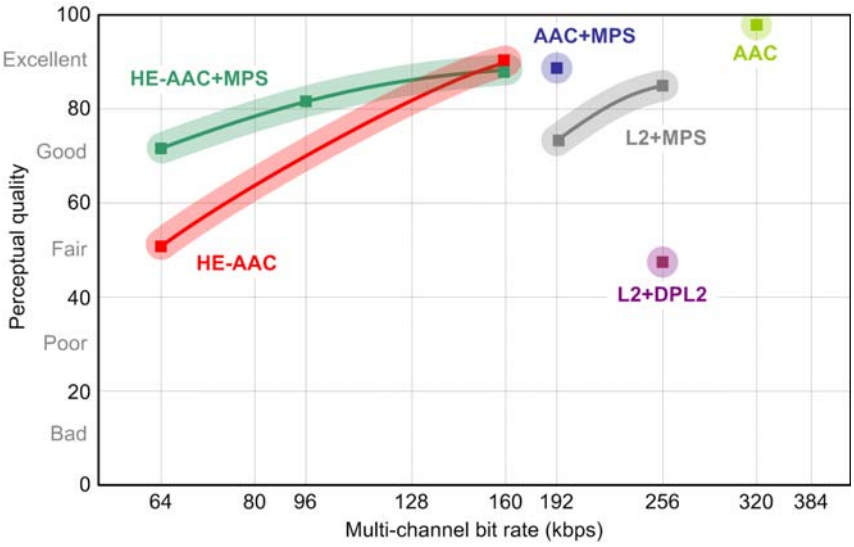

Figure 6
Rate-distortion performance of MPEG Surround

Optional encoding tools

In addition to the compelling compression efficiency, MPEG Surround also provides a number of other significant features, ensuring that it is the best choice for many broadcast systems.

Channel scalability

MPEG Surround offers a wide range of multichannel configurations including conventional 5.1 and 7.1 mixes. In its highest implementation level, the standard supports up to 32 input channels.

External or artistic down-mix

MPEG Surround is not only able to operate with the internal downmix of the multichannel input to the stereo core signal. An "artistic" downmix, for instance a dedicated stereo mix produced by the sound engineer in the studio, can be used as an externally-supplied input for the core coder. MPEG Surround is able to store the differences between the artistic and internal downmix efficiently, allowing it to steer the upmix process accordingly. Of course, this only works if the input of all

sources (artistic downmix signal and multichannel signals) are provided time-synchronously, and that the artistic downmix signal contains all relevant parts of the multichannel signal.

Binaural decoding

This feature brings very significant benefits for the enjoyment of multichannel audio on mobile devices. It is well-known that multichannel audio can be presented on headphones by means of binaural processing, for instance with Head-related Transfer Functions (HRTFs) or Binaural Room Impulse Responses (BRIRs). The MPEG Surround engine includes this functionality in the decoder. Thanks to the parametric nature of the spatial data and the signal flow, this signal processing can be done very efficiently without generating the actual 5.1 loudspeaker signals before binauralization takes place. As a result, it is possible to create a binaural representation of multichannel audio on mobile devices that requires only a fraction of the processing required for a discrete 5.1 coding scheme with a binaural post-processor.

Enhanced matrix mode

For legacy transmission channels that still work with a matrix-compatible downmix signal and are not able to carry any MPEG Surround parameter information, an MPEG Surround decoder can be run in "enhanced matrix mode". The decoder estimates MPEG Surround parameters from the downmix signal. Even in this "0 kbit/s" mode, MPEG Surround still outperforms conventional matrix decoders [9].

Matrix compatible mode

As opposed to standard operation, where the MPEG Surround encoder creates an energy-balanced downmix of the multichannel input, the encoder can be configured to create a matrix-compatible downmix by introducing the necessary phase relations. This allows the core downmix signal to be handled by legacy decoders such as A/V receivers that are not equipped with MPEG Surround but feature a matrix-based surround up-mix, e.g. Dolby Prologic II. If an MPEG Surround decoder is available, the matrix operation is invertible to enable an unaltered multichannel output.

Summary

MPEG Surround provides a highly efficient and backwards compatible extension method for the seamless transition to multichannel audio in various broadcasting systems, and is already part of many European and global industry standards. Offering high-quality surround sound at stereo bitrates, MPEG Surrounds avoids the simulcast of stereo and surround audio and therefore enables 5.1 audio, even in bandwidth-limited TV services.

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Harald Fuchs received his diploma in electrical engineering from the University of Erlangen, Germany in 1997 and joined Fraunhofer IIS in the same year. He has more than 12 years experience in video coding, audio coding and multimedia systems. His current main interests are IPTV and Internet TV.

Mr Fuchs contributes to several standardization organizations including DVB, Open IPTV Forum, MPEG and OMA, with a current focus on DVB. Since 2007, he has been chairing the Content Delivery Task Force of the DVB CM-IPTV ad-hoc group.

Olaf Korte has been with Fraunhofer IIS since 1994. As head of the Digital Broadcast Applications Group, he is deeply involved in the specification and development of many kinds of services for digital broadcast systems such as DAB/DAB+/DMB and DRM/DRM+. This includes for example surround sound, multimedia, telematic services, car infotainment, conditional access systems and broadcast content server technology.

Mr Korte and his immediate colleagues are members of several international groups at WorldDMB, Digital Radio Mondiale, the EBU and DVB. With regard to the German market, he is a member of *BMWi Forum Digitale Medien* and *Allianz Bayern Innovativ AV3000*. In the USA, he is also a member of the National Radio Systems Committee (NRSC).

Johannes Hilpert has been head of the group "Audio Coding and Multimedia Software" at Fraunhofer IIS since 2001. He is a co-developer and project editor of the MPEG Surround standard.

Mr Hilpert received his Diploma in Electrical Engineering from the Friedrich Alexander University in Erlangen in 1994. Since then, he has worked on audio-related topics at Fraunhofer including objective measurement of audio quality, real-time implementation of perceptual audio codecs on Digital Signal Processors, and the development and deployment of audio standards such as MPEG Layer 3, MPEG AAC, MPEG Surround and MPEG SAOC.

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