WHITE PAPER

EXPERIENCING MULTICHANNEL SOUND IN AUTOMOBILES: SOURCES, FORMATS AND REPRODUCTION MODES

Mercè Serra and Olaf Korte, Fraunhofer IIS

Recent developments in audio technology mean that content suppliers now have an exciting opportunity to deliver high-quality multi-channel sound to consumers. In contrast to previous attempts using physical media such as DVD-A or SACD, the new method is handy, convenient, consumer-friendly and inexpensive, and allows for content distribution via digital radio, TV broadcasting, Internet streaming or download from online stores. As well as the living room and portable devices such as mobile phones and iPods, the car provides an ideal environment in which to enjoy this impressive media experience, either for surround music by itself or in combination with video.

As might be expected from such a fundamental change in approach, achieving 'natural' and compelling multi-channel sound reproduction in the car constitutes a significant challenge. This article will discuss two recommended and highly practical options for implementing in-car multi-channel sound. The technology used to deliver this new audio experience is the ISO standard MPEG Surround, which combines bit-rate efficiency and backwards-compatibility to legacy stereo environments. This article will elaborate on the basic codec design and provide an overview of industry adoption to date.

VERSION 2017

1. BACKGROUND

Surround music became available to consumers in the late 1990s with the introduction of the first SACD (Super Audio CD) and DVD-A releases. In both cases, the developers claimed that their 5.1 channel (or larger) surround formats could open a new dimension to the enjoyment of music, allowing listeners to experience old favorites and brand new releases in a new and compelling way. While much of the initial media attention focused on the potential for home surround sound, these new formats also had implications for the automotive sector, with some luxury car manufacturers seeking to bring 5.1 configurations to their higher-end models.

In reality, the audio revolution implied by these new formats proved to be rather short-lived. The varying specifications of the two competing formats resulted in widespread public confusion, while the need for costly new playback devices and the unwieldy form factor also discouraged potential early-adopters. The good audio quality offered by existing CD technology, the convenience of compressed digital media formats (e.g. mp3) accessible via portable music players and the general need to invest in more expensive hardware to make the most of the new formats also left many consumers with the feeling that SACD or DVD-A was an expensive indulgence that simply could not be justified. While these formats enjoy the continuing support of some hi-fi enthusiasts, their appeal remains limited to this niche and has not crossed over to the mass market of music consumers. (It should be noted that the initial format competition (with HD DVD) as well as the burgeoning digital/online music trend may also have affected the adoption of Blu-ray as an audio format.)

Theoretically at least, any developments that enhance the convenience of personal music consumption are to be welcomed, but there is also a sense of regret about the failure of surround formats to connect with a wider audience. As anyone who has experienced an optimized 5.1 audio demonstration will know, the surround sound experience has the potential to put the listener at the heart of a performance and re-engage them with music in a manner that can only be compared to a live concert. From a legendary performance of a Shostakovich or Mahler symphony newly rendered in multichannel audio, to a 5.1 mix of a seminal Miles Davis or Pink Floyd album, surround audio can make familiar music 'new' and exciting all over again. And in the car, manufacturers and content providers have the ideal venue for a revelatory surround audio experience, thanks to the defined loudspeaker and passenger positions, and the availability of high quality fully discrete multichannel sound systems.

In recognition of the dormant potential of surround audio, MPEG initiated the development and standardization of the non-physical digital format, MPEG Surround. The resulting technology offers manufacturers and content suppliers the opportunity to bring 5.1 content into a vehicle via digital radio, mobile TV, and Internet streaming as well as connectivity to docked nomadic devices such as iPods. A convenient, high quality surround sound experience is guaranteed – and without any of the practical drawbacks associated with its physical media equivalents.

2. CURRENT STATUS OF MULTICHANNEL SOUND IN AUTOMOBILES

During the last decade, the improved audio quality provided by digital sources such as CDs, DVDs, portable music players and digital radio receivers has meant that premium audio systems in automobiles have grown in popularity. In the near-future, it is realistic to expect that the success of premium sound systems will rely not only on high power amplification and the number and quality of installed loudspeakers, but also on the ability to reproduce multichannel audio recordings. [In this context, „multichannel" means the use of more than two audio channels for the recording. The most popular 5.1 format includes three channels for speakers at the front (front left, center, front right), two for the rear (surround left and surround right) and one for low-frequency effects (subwoofer).]

One of the reasons for multichannel sound becoming a defining characteristic of premium sound systems is that cars offer an ideal environment in which to enjoy high-quality sound reproduction. Away from the distractions of the home or workplace, car occupants can look forward to an uninterrupted period of time (providing they have switched off their mobiles, of course!) in which to enjoy a favorite radio program or album.
Listening to multichannel sound provides passengers with a pleasing, enveloping experience that gives them the sensation of being right in the middle of a performance. Furthermore, audio system suppliers and car manufacturers understand the precise acoustic characteristics of the vehicle and the ideal position of loudspeakers and listeners in what is a self-contained, well-defined environment. As a result, they can adjust the sound system to guarantee optimal sound reproduction. Even more importantly, the consumer does not need to worry about speaker positioning or wiring in the car as the necessary infrastructure is in place at the time of purchase. This alone represents an important contrast with the domestic environment, where consumers will need to take extensive advice before acquiring a multichannel home theatre system and may subsequently need to pay a qualified installer/integrator to set-up the new equipment.
But despite the innate suitability of the automobile for multichannel sound reproduction, and the fact that most low- to middle-range vehicles now feature at least four loudspeakers, many audio systems are still configured for stereo reproduction only.
Among those vehicles where multichannel playback is possible, the approach is generally to feed all playback signals, both stereo and multichannel, through a matrix-based upmixing process that synthesizes multichannel sound from a two-channel source simulating five to seven channels, resulting in limited surround image quality. Other high-quality upmixing systems try to achieve superior results using delays or reverb to synthesize signals for the rear channels.

At the present time, only a small number of automobile manufacturers provide high-quality discrete multichannel sound reproduction from six-channel recordings on DVD-Audio or SACD. But with fewer surround audio titles being released due to limited consumer demand and the costs associated with reissue production, the availability of music in these formats is limited – and likely to become even more so in the future. Moreover, the transfer of discs between the car and the home is inconvenient for the user, who may well regard this necessity as a retrograde step in the era of easy digital music consumption.

Fraunhofer
IIS

3. AVAILABILITY OF MULTICHANNEL AUDIO-ONLY CONTENT

Most of the multichannel content available today is video-related, with the vast majority of commercial DVD-video titles released containing multichannel sound in 5.1. In the United States almost all television programs covering sports, movies, talk shows and dramas are broadcast in multichannel format.

But what is the current situation for audio-only content? In truth, it has only begun to realize its potential in either the physical or virtual realms. As we have seen, physical formats have failed to connect with the general public, while virtual services have been dominated by stereo content to date. And with illegal downloading adding further pressure to record company revenue streams in recent years, there has also been a reduction in enthusiasm for reissuing existing content in new formats.

The broadcasting sector offers more reason to be upbeat. Some European public broadcasters are already using the DVB-S high-quality television distribution system for delivery of content including multichannel audio, paving the way for the wider availability of domestic multichannel decoders that will interpret both TV and radio programs in this format. ORF (Austrian Broadcasting), BR (Bavarian Broadcasting) and WDR (West German Broadcasting) are among the internationally-recognized broadcasters to deliver live concerts and radio dramas in this way on a regular basis.

4. CHALLENGES ASSOCIATED WITH DELIVERY

Current distribution of multichannel sound to a general audience is conducted primarily over digital television services. However, current systems offering multichannel sound, such as DVB-S, can only be used in stationary environments with a satellite dish and are therefore not applicable for automotive applications. Other distribution channels such as digital radio systems (or internet radio via wireless networks) could offer mobile reception of multichannel audio, but up to now their small channel capacity has limited the provision of audio services to stereo programs only. In addition, multichannel coding formats currently used in DVB-S, for example Dolby Digital (AC3), are not backward-compatible and so require the distribution in parallel to the stereo stream, resulting in a high bandwidth occupation for broadcasting.

Aware of the need for a multichannel format that combines efficient delivery, high audio quality and backwards-compatibility to legacy devices, a new format for encoding multichannel sound was standardized within MPEG: MPEG Surround.

MPEG Surround is a perfect fit for the music industry, allowing record companies to issue 5.1 content without accruing the high production (remixing/remastering), packaging and distribution expenses associated with conventional disc-based releases. Moreover, easy implementation and suitability for use with a wide variety of delivery methods (digital radio, mobile TV, Internet streaming, iPod, etc) mean that MPEG Surround also represents the most flexible and cost-efficient path to a bright new future for multichannel audio.

5. MPEG SURROUND – SUPERLATIVE MULTICHANNEL SOUND FOR NEXT GENERATION SERVICES

Developed by Fraunhofer IIS, Dolby Laboratories, LSI Corporation and Philips, MPEG Surround is a feature-rich open ISO standard compression technique for multichannel audio signals. This standardized format for the distribution of multichannel sound allows 5.1 content to be transmitted over digital broadcasting services, or downloaded/streamed from online media stores. Operating on top of any core audio codec – including AAC, HE-AAC and MPEG-1 Layer II – the system provides a comprehensive feature-set, including highest multichannel and stereo audio quality, operation at bit rates currently used for compression of stereo signals, full backwards-compatibility to stereo equipment, wide scalability in terms of the multichannel image description bit rate, and binaural multichannel sound reproduction capability for stereo headphones. Employing transmitted side information in the receiver to produce a faithful reconstruction of the original multichannel source, MPEG Surround enables high-quality multichannel sound experiences at home, in the car and on the move. Additionally, the same music file also plays back on conventional stereo devices in stereo quality.
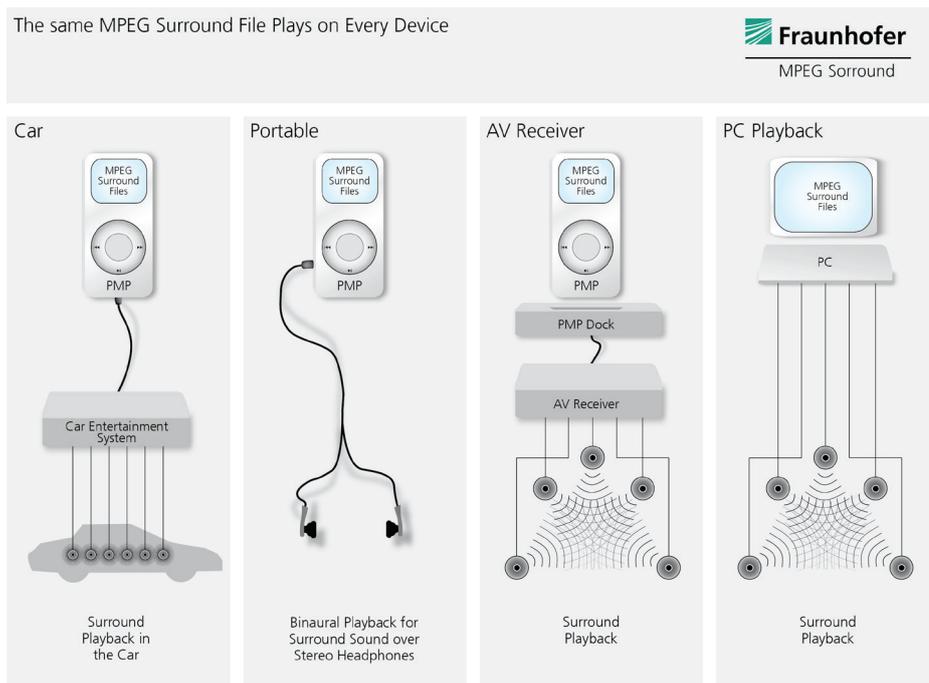

Figure 1: MPEG Surround - one file for all

From the very first transmission trials, MPEG Surround has proven itself to be a viable and attractive choice for new multichannel services. As a result, the format has already been adopted by several internationally-recognized digital broadcasting standards, such as WorldDMB (including DAB, DAB+, DMB; also DMB Radio in France), DRM (Digital Radio Mondiale), DVB-H, ATIS-IIF (IPTV Interoperability Forum), Open IPTV and the forthcoming ISDB-Tmm terrestrial mobile multi-media standard in Japan. It has also become part of the DLNA digital home media standard and is under consideration for mobile streaming services in 3GPP. It has also been proposed as the multichannel audio codec for Internet streaming as part of the Rich Audio Profile, currently under standardization at IMDA (Internet Media Device Alliance).

6. HOW DOES MPEG SURROUND WORK?

MPEG Surround is based on the principle of spatial audio coding, which entails the gene-
ration of a mono or stereo downmix from the multichannel input signal in the encoder,
with additional parametric side information (3-32 kbit/s or more) extracted to guide the
upmix process in the decoder. This parametric side information, referred to as the MPEG
Surround bit-stream, is hidden in a backwards-compatible way in the stereo bit-stream
and contains spatial data for the generation of 5.1 channels from the stereo downmix.
All audio compression schemes provide transport mechanisms for such ancillary data,
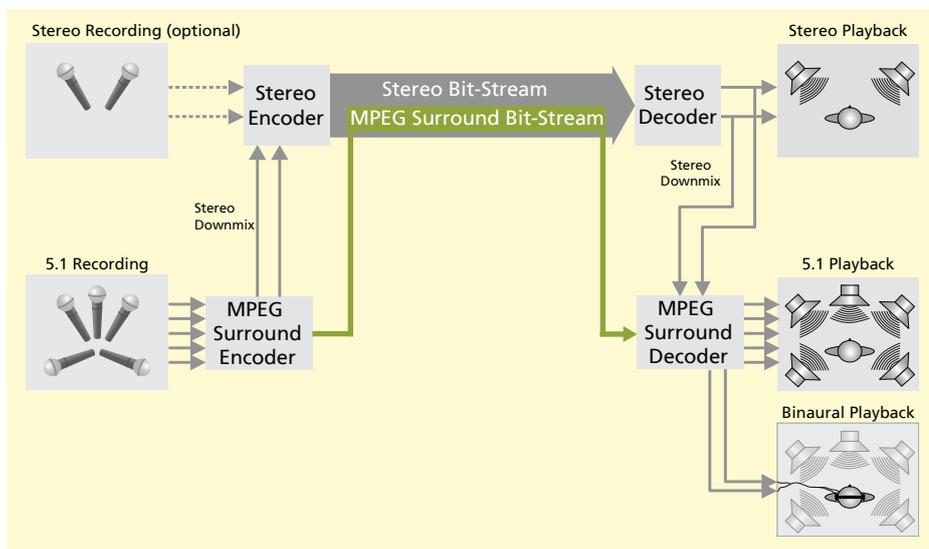ensuring the correct time alignment between the spatial and compressed audiodata.

Figure 2: MPEG Surround mode of operation

A legacy decoder which is not capable of detecting the hidden MPEG Surround bit-stream
will decode the mono or stereo downmix. Consequently, simulcast of the multichannel
and the downmix signal is not required with MPEG Surround. Additionally, MPEG
Surround supports a binaural rendering mode to allow users to experience a virtual
multichannel loudspeaker setup over conventional stereo headphones.

MPEG Surround combines the advantages of the two existing methods for coding multi-
channel content. Firstly, it provides very-high audio quality output of discrete compression
technologies, which process every channel separately. Secondly, it compresses multichan-
nel sound at bit rates typically used for the coding of stereo material. Matrix surround
systems embed multichannel content in a stereophonic downmix and „blindly" decode
the signal to multichannel with limited spatial audio quality. By contrast, MPEG Surround's
approach overcomes the disadvantages often associated with discrete or matrix surround
coding systems, including large data-rate requirements and disappointing audio quality.

7. MPEG SURROUND FOR AUTOMOTIVE APPLICATIONS

MPEG Surround has the potential to revolutionize multichannel content delivery (music & video), which has significant implications not only for content producers, broadcasters and consumer electronics companies, but also for car makers. This new format gives automobile manufacturers the chance to bring 5.1 content into a vehicle via digital radio, mobile TV, internet streaming and connectivity to docked portable devices such as iPods.

With MPEG Surround, radio stations can broadcast their programs in multichannel, which can be received in a car environment over digital radio services (e.g. DAB, DAB+, DRM) or satellite radio. There is exciting potential, too, for front- and rear-seat entertainment applications, including multichannel digital TV via DMB, DVB, ISDB, ATSC, etc. Increasing data-rates and the availability of flat-rate services in the mobile sector mean that MPEG Surround data streams or downloaded files can also be received directly in the car over existing 3G or future 4G networks. Internet Radio and IPTV are among the service offerings that could be realized in this way.

New audio systems incorporating MPEG Surround allow consumers to dock their portable music players, such as mp3 devices or iPods, for multichannel playback within the car. MPEG Surround content previously stored in an iPod can be loaded onto a car hard disc drive for subsequent playback or interfaced directly with a high-quality audio system. Premium sound systems supporting MPEG Surround reproduce music in high-quality multichannel, while compatibility with stereo sound systems is maintained. This versatility of playback – which is arguably unprecedented in the consumer audio field to date – means that the same music files can deliver both the usual stereo quality over legacy devices and multichannel playback via in-car or home theatre surround systems.

8. MPEG SURROUND INTEGRATION IN AUTOMOBILES

Irrespective of the format employed, playback of multichannel sound requires a multichannel power amplifier for independent control of the 5.1 input channels. Multichannel amplifiers are mainly located in the trunk, but may also be situated behind the dashboard or under the driver's or passenger's seat. They may also include a built-in digital signal processor (DSP) for equalization, crossover filters or loudspeaker time-alignment delays.
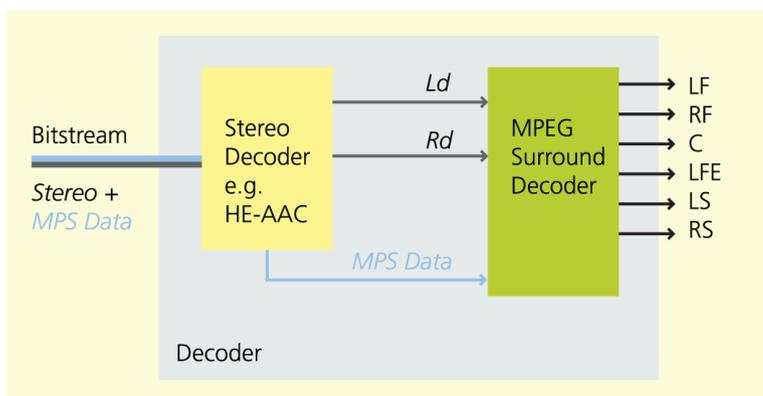

Figure 3: MPEG Surround decoder principle

As previously mentioned, an MPEG Surround file or stream can be experienced in the car via digital broadcast, 3G/4G services or a connected portable music player. To be able to decode MPEG Surround content and reproduce high-quality multichannel sound, the integration of two main components is required. First, a stereo decoder is needed to decode the received bit-stream (e.g. AAC, HE-AAC or MPEG-1 Layer II encoded downmix) to stereo (Ld, Rd). Secondly, the actual MPEG Surround decoder generates a psychoacoustically discrete multichannel audio signal from both the stereo audio data and the MPEG Surround spatial parameters (MPS data).

There are several possible approaches towards the integration of the stereo decoder and the actual MPEG Surround decoder in the car. In many cases - for example, when receiving MPEG Surround over digital radio - the tuner already includes a stereo decoder. The sections below ('Head unit integration' and 'Amplifier integration') outline two recommended configurations for the implementation of MPEG Surround in standard car audio environments. Note that in each of the options, both the stereo decoder and the MPEG Surround decoder are placed in the same location, enabling them to serve as one single module. This approach enhances the efficiency of the surround implementation and avoids synchronization problems between the stereo data and the MPEG Surround parametrical information.

It should also be observed that in both options, stereo PCM can still be provided for use in stereo playback scenarios, e.g. rear-seat entertainment over headphones. Alternatively, MPEG Surround's binaural headphone mode allows listeners to experience a virtual multichannel loudspeaker setup when using conventional stereo headphones for rear-seat entertainment applications. However, for reasons of simplicity and clarity, the MPEG Surround binaural use case is not depicted in the diagrams below.
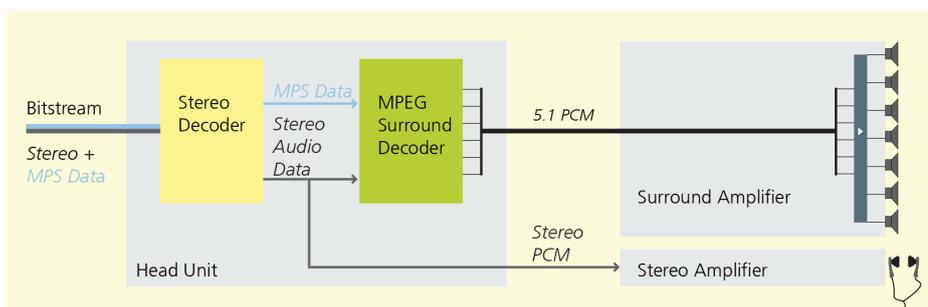
9. HEAD UNIT INTEGRATION

Figure 4: Principle of head unit integration

In this option, the stereo and MPEG Surround decoders are both integrated in one single module in the head unit. The received MPEG Surround bit-stream is converted to a 5.1 PCM signal, which is transmitted to the multichannel amplifier. Additionally, a stereo PCM signal can also be transmitted for backwards-compatibility to applications featuring stereo amplifiers.

This is the recommended option for all scenarios in which the transmission channel between the head unit and the amplifier offers sufficient bandwidth for 5.1 PCM, and it is possible to integrate an MPEG Surround decoder into the head unit. Please note that at

48kHz, the transmission of 5.1 PCM requires less than 5 Mbit/s and the transmission of stereo PCM only about 1,5 Mbit/s.

10. AMPLIFIER INTEGRATION

Once again, the stereo and MPEG surround decoders are situated in a single module – but on this occasion, the location is the multichannel amplifier.

The MPEG Surround bit-stream received in the head unit (including the encoded stereo and the MPEG Surround data) is forwarded directly to the multichannel amplifier, where it is decoded to generate a 5.1 channel PCM signal. Additionally, to re-use the existent head unit architecture and guarantee backwards-compatibility to stereo applications, a second stereo decoder may be included in the head unit. In most cases, a stereo decoder is already part of the receiver module.
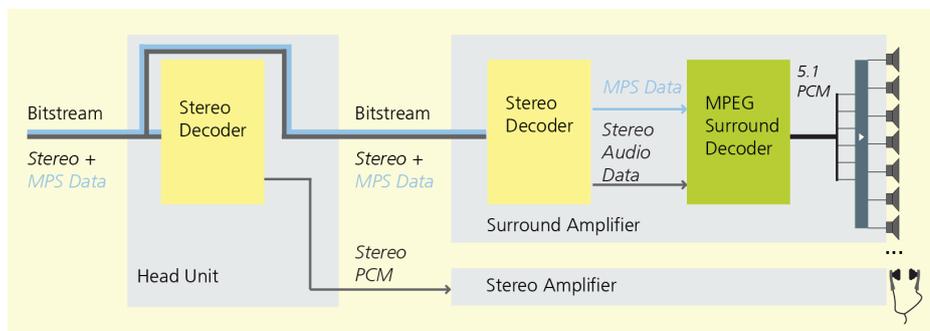

Figure 5: Principle of amplifier integration

11. AVAILABILITY AND LICENSING OF MPEG SURROUND SOFTWARE

Product-ready MPEG Surround implementations are available for PC platforms and many common embedded and digital signal processors (DSPs) as they are used in automotive digital radio receiver and amplifier designs:

- TI C6x, Jacinto, OMAP, DaVinci
- ARM
- PC (Win/MacOS X/Linux)
- ADI Blackfin, Sharc
- Power PC processors
- MIPS
- Apple iPhone® SDK, Android OS

A patent licensing program for MPEG Surround is administered by Via Licensing, Inc. to enable manufacturers of encoding and decoding software/equipment to gain easy access to the essential IP under fair and reasonable terms of licensing.
Please visit www.vialicensing.com for more information or contact info@vialicensing.com.

For more information about MPEG Surround, please visit http://www.mpegsurround.com.
Please contact Mercè Serra (merce.serra@iis.fraunhofer.de) if you have any further queries.

12. LITERATURE

[1] „Latest developments in low bit-rate and high-quality multi-channel automotive audio", Marc Gayer and Robert Bleidt, Fraunhofer IIS, AES 35th International Conference, Dearborn, Michigan, USA, 2009 June 2-4

[2] „MPEG Surround – A Bright New Future for Surround Sound", Matthias Rose, Jan Nordmann, Fraunhofer IIS, Fraunhofer USA DMT, Information Quarterly Magazine, Volume 7, Number 4, 2008

ABOUT FRAUNHOFER IIS

The Audio and Media Technologies division of Fraunhofer IIS has been an authority in its field for more than 25 years, starting with the creation of mp3 and co-development of AAC formats. Today, there are more than 10 billion licensed products worldwide with Fraunhofer's media technologies, and over one billion new products added every year. Besides the global successes mp3 and AAC, the Fraunhofer technologies that improve consumers' audio experiences include Cingo® (spatial VR audio), Symphoria® (automotive 3D audio), xHE-AAC (adaptive streaming and digital radio), the 3GPP EVS VoLTE codec (crystal clear telephone calls), and the interactive and immersive MPEG-H TV Audio System.

With the test plan for the Digital Cinema Initiative and the recognized software suite easyDCP, Fraunhofer IIS significantly pushed the digitization of cinema. The most recent technological achievement for moving pictures is Realception®, a tool for light-field data processing.

Fraunhofer IIS, based in Erlangen, Germany, is one of 69 divisions of Fraunhofer-Gesellschaft, Europe's largest application-oriented research organization.

For more information, contact amm-info@iis.fraunhofer.de, or visit www.iis.fraunhofer.de/amm.