WHITE BOOK
Beyond HD
– Update August 2014 –

Working Group “Ultra HD”
of the German TV-Plattform
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Preface

At the IFA 2013 Ultra HD display panels in various sizes and models could be found at the stands of nearly every device manufacturer, and “Ultra HD” was one of the show’s key topics. Reasons enough for the German TV Platform to dedicate a special publication not only to a description of the status quo in HDTV and 3D TV but also to this new trend of ultra-high-definition technology. The White Book “Beyond HD” was originally published to coincide with the opening of the fair on 6 September 2013, which featured a joint “Ultra HD (4K)” stand under the aegis of the German TV Platform. Due to the rapid pace of development in and around this new dimension of television, this trade publication has become available in the meantime in an updated version (February 2014), in both German and English. These updates were published in time for the 23th Symposium of the German TV Platform, where 160 attendees discussed the question: “What is Ultra HD good for?” under the aspects of market relevance, production, and technology.

In 2014, Ultra HD will once again be one of the dominating topics of the show in the shadow of Berlin’s Radio Tower. And since a lot of things have happened, once again, since the publication of the second edition of the White Book, six months ago, we are now publishing this update to provide information on the very latest developments relating to Ultra HD.

Aside from taking a look at the status quo of the market development of Ultra HD in Germany, the present document will focus primarily on the progress at the various stages of the Ultra HD production chain. On 26 April 2014, we saw the first full live coverage of a German Bundesliga soccer match in Ultra HD, broadcast via satellite in the new H.265/HEVC standard, and during the 2014 FIFA World Cup in Brazil, which turned into a triumphant success for the German team, a few Ultra HD productions were realized, but unfortunately none of them was viewable live in Germany. Moreover, additional technological improvements will be presented and discussed, which will probably become relevant in Phase 2 of the Ultra HD market launch, further enhancing the overall visual impression and viewing experience with Ultra HD, beyond the mere quadrupling of pixels (Phase 1).

At IFA 2014, the German TV Platform will dedicate the major part of its significantly expanded stand to Ultra HD. Initiated by the working group “Ultra HD” (formerly “HD3D” project group), at TecWatch in hall 11.1, interested visitors may – in addition to watching a state-of-the-art demonstration of Ultra HD Phase 1 via various distribution channels – also get a first impression of the possible features of Phase 2, such as High Dynamic Range.

Stephan Heimbecher (Sky Deutschland)
Head of the Working Group “Ultra HD” of the German TV Platform
1. Introduction of Ultra HD

In the course of 2013, the industry has developed a common understanding regarding the two-tiered introduction of Ultra HD. Phase 1 is intended to allow a short-term market launch (2014/2015) on the basis of currently available Ultra HD display panels and is primarily limited to quadrupling pixel resolution (3,840x2,160), compared to Full HD (1,920x1,080).

Phase 2 would take further improvements into account, including, for example, High Dynamic Range (HDR) and an extended color gamut. The goal of all these efforts is to achieve an even deeper immersion of the viewer into the action on screen by improving both audio and video. Due to a lack of standards and adequate device technology at this time, however, a launch of Phase 2 should not be expected any sooner than 2017/2018.

1.1 UHD-1 Phase 1

The DVB specification for UHD-1 Phase 1 was adopted in early July 2014 by the DVB Steering Board. DVB-UHDTV includes an H.265/HEVC profile for DVB Broadcasting Services and extends ETSI TS 101 154 (Specification for the Use of Video and Audio Coding in Broadcasting Applications based on the MPEG-2 Transport Stream). In addition to quadruple pixel resolution, the system allows frame rates of up to 60 Hz (fps) and is based on a bit depth of 10 bit. Level 5.1 of the H.265/HEVC Main 10 profile is designated for 2160p content, while HD services with up to 1080p are supported by Level 4.1.

1.2 UHD-1 Phase 2

In June 2014, the prospects concerning Phase 2 of the Ultra HD launch have taken further shape, following discussions within, for example, DVB and FAME (Forum for Advanced Media in Europe). Elaborating on the two-tier model established a year earlier, the concepts regarding the features of Phase 2 were further refined and detailed. Nonetheless, adequate amounts of time had to be scheduled to allow DVB, for example, to specify the commercial requirements for UHD-1 Phase 2. Even though there is a basic consensus by now that High Dynamic Range (HDR) should play an important role, it has yet to be defined what exactly HDR will eventually imply. There is also a fundamental agreement on a High Frame Rate (HFR), an enhanced audio system for Ultra HD, and an extended color gamut. However, there are numerous details yet to be discussed in these areas, making it unlikely for DVB Commercial Requirements to be published any sooner than late 2015. A corresponding technical specification should then be available a year later (late 2016, at the earliest).

It must be considered that at least some of those enhancements and improvements envisioned for Phase 2 of Ultra HD will have a significant impact, for instance, on the production processes of Ultra HD display panels, especially with regard to HDR and the extended color gamut. At the same time, a downward compatibility with UHD-1 Phase 1 is aimed at, which would allow service providers to offer Ultra HD content to users of both Phase 1 and Phase 2 devices without requiring a simulcast. Whether and how these compatibility requirements can be implemented technically is still unclear.
1.2.1 High Dynamic Range

A higher spatial resolution alone will probably not suffice to constitute the next big step of the television experience. A more pronounced contrast – generally referred to as High Dynamic Range (HDR) – is an essential factor in exploiting the full potential of the enhanced image quality.

In order to define a color phenomenon, both its color and intensity are required parameters. The so-called “color volume” constitutes the range of available colors in all their intensities. The combination of Rec. ITU-R BT.709 and Rec. ITU-R BT.1886 shows that not all colors are available to be displayed in all intensities.

The specifications for luminance and contrast, which date back to the technical capabilities of CRT monitors, are considered inadequate by the motion-picture and television industry today. The motion-picture industry is demanding a maximum luminance in the area of 10,000 cd/m² and a black level of 0.005 cd/m², corresponding to a contrast (ratio) of 2,000,000:1. Rec. ITU-R BT.709, however, which is still the valid standard today for HDTV, only specifies a maximum luminosity of 100 cd/m², and today’s state-of-the-art display panels typically support no more than 300-400 cd/m². At CES 2014, Dolby and Technicolor, among others, announced their own HDR solutions. One key aspect in the introduction of new HDR options is the necessity to provide acceptable video for the UHD-1 Phase 1 displays, which will be already in existence at that time and which will support no more than 1,000 cd/m². A variety of approaches have been suggested, which still need further discussion. SMPTE is currently considering a standardization of HDR, but nobody can say at this time, when such a standard might come into effect.
In mid-June 2014, the DVB Project and the European Broadcasting Union (EBU) organized a workshop on the subject of “High Dynamic Range,” which brought together all notable experts for one day. In lectures and technical demonstrations, four proposals (by BBC, Dolby, Philips, and Technicolor) for the realization of HDR were presented. All solutions share a complete downward-compatibility with UHD-1 Phase 1 devices by transmitting any additional data that may be required in a separate data stream. In addition, background information from a medico-physiological and from a technological point of view was shared at the workshop. The subsequent discussions gave attendees an opportunity to exchange their thoughts and ideas in depth. The event, however, partially suffered from the fact that the users of the new technology – the motion-picture and television industry – were underrepresented.

The day after this workshop, the DVB Project’s commercial “UHDTV” working group met to discuss the basic conditions for a launch of UHD-1 Phase 2 in the years 2017/2018. Initial contributions were passed on to the Moving Picture Experts Group (MPEG) for the expected steps to be considered in the data compression standards which MPEG maintains. Within the framework of IBC 2014, the UHDTV working group will continue to develop a comprehensive concept from a commercial point of view.

HDR is still extremely demanding on the production side, so that virtually no HDR content is available. On the consumer side, it is still anybody’s guess which luminance value is realistically achievable for consumer display panels.
1.2.2 High Frame Rate

When it comes to motion, the spatial resolution is reduced in all television systems by temporal integration effects (exposure time) within the camera as well as similar effects in playback and viewing on a screen. In these cases, the limiting factor for the dynamic sharpness of an image is no longer the number of pixels in a display panel (spatial resolution) but the motion or panning speed and the frame rate.

For this reason, doubling the number of pixels should go along with doubling the number of frames per unit of time, less the dynamic sharpness drop below the static sharpness under identical conditions for image content (i.e. same speed relative to frame width or height).

For Phase 2 of UHDTV, the topic of High Frame Rates (HFR) is therefore under discussion, meaning a frame rate of 100 Hz or fps (frames per second) – or possibly 150 fps –, compared to 50 fps in Phase 1. ITU Recommendation ITU-R BT.2020, which applies to UHDTV, contained 120 Hz in its first version, but not 100 Hz; this value, which is important for the European market, has, in the meantime, been added.

1.2.3 Enhanced Audio Systems

In the medium term, the enhanced visual experience of UHDTV should be backed up by a more impressive sound, too. By now, the options for improved next-generation audio systems for UHD-1 Phase 2 have become much more specific. Apart from a compatibility with customary channel-based formats, such as stereo or 5.1, new approaches like MPEG-H, Dolby AC-4, and DTS UHD allow the broadcast of channel-based, object-based, and scene-based audio formats as well as mixed forms with a significantly enhanced immersiveness. Moreover, the audio decoder will adapt the audio signal perfectly to the playback situation, creating the best possible sound experience, even with inconveniently placed speakers, for example. Other features include the enabling of interactive elements, Dynamic Range Control (DRC), or the playback of immersive sound via headphones.

On the production side, the audio system will lead, step by step, into the future of television, but it will also account for the growing diversity of the receiving systems.
1.2.4 Extended Color Gamut

An improved representation of color may develop into a distinctive feature and key USP for UHD content and UHD consumer devices. In Version 1.1 of the White Book "Beyond HD", we showed that, in ITU Recommendation ITU-R BT.2020, the UHD standards already contain an option that may lead to a significant improvement of the color experience for the viewer.

Through their subsidiary, MovieLabs, the Hollywood majors have brought up another proposal, contained in their document, "MovieLabs Specification for Next Generation Video – Version 1.0" [source: http://movielabs.com/ngvideo/]. The document suggests using the XYZ color space for encoding color in the file-based movie distribution of the future (via networks or physical media). The XYZ color space is a virtual color space already used today in digital theatrical distribution. The illustration below shows the XYZ color space, compared to the RGB color spaces according to Recommendations ITU-R BT.709 and ITU-R BT.2020.
Color volume of Rec. ITU-R BT.709
with a maximum luminance
of 100 cd/m², restricted by the still valid
technological limitations
from the era of CRT monitors

The XYZ color space allows the encoding of all visible colors and thus even exceeds Rec. ITU-R BT.2020. When using the XYZ color space as a broadcast standard, the display device has to convert the XYZ pixel information into the device-specific RGB color space. This has the advantage that a correct color display will be achieved on any device, regardless of their specific color space.

MovieLabs’ use case for XYZ provides for content to be encoded in the XYZ color space, with a color sampling of 4:4:4 as well as a (yet to be defined) 4:2:2 or 4:2:0 subsampling to be supported. The subsampling is possible, because the Y component of XYZ is identical to the luminance signal and the color information is thus concentrated in X and Z.

The advantage of using the XYZ color space for “packaged media” would be that it implies no restrictions regarding the color representation on future devices: newly marketed devices with an extended color gamut would be able to display existing XYZ content with an improved color representation without any changes to the encoding standard. For this reason, the encoding in XYZ can be considered future-proof.

The drawback of the XYZ color space lies in its low encoding efficiency: As the color triangle shows, large parts of the XYZ color triangle are outside the range of visible colors. XYZ color coordinates corresponding to these areas must not be applied. A quantization with no less than 12 bit, as suggested by MovieLabs, is thus required. The costs on the consumer side for the device-based color-space conversion via LUTs or, alternatively, via a matrix transformation for each pixel, should also be taken into account.

In addition to the XYZ color space, MovieLabs’ proposal includes a High Dynamic Range with an encodable luminance range between 0.005 cd/m² and 10,000 cd/m² (cf. chapter 1.2.1) as well as a perceptually spaced non-linear pre-equalization of the color signals to allow efficient encoding. So far, it has not been proposed that XYZ be used for broadcast distribution.
2. Status Quo of Ultra HD in Germany

With two live test broadcasts in the spring of 2014, Ultra HD has taken an enormous leap forward in Germany. At the Bundesliga soccer match between FC Bayern Munich and Werder Bremen on 26 April 2014, it was possible, for the first time, to close the live production chain for an Ultra HD broadcast in the new H.265/HEVC standard. The game was broadcast live via satellite by Sky Deutschland, using six Ultra HD cameras. The broadcaster repeated a similar test – again with the support of numerous partners in the industry – on 17 May 2014 at the “DFB Cup” final soccer match between Borussia Dortmund and FC Bayern Munich. There were also a total of three productions in Ultra HD at the FIFA World Cup in Brazil, which, unfortunately, were not viewable live in Germany.

2.1 Market for Consumer Devices

Three words can summarize the current trend in the TV market: larger, sharper, smarter. Especially the consumer demand for large screen sizes is still growing. This trend is corroborated by the results of a recent representative study by gfu – Gesellschaft für Unterhaltungs- und Kommunikationselektronik, conducted in May 2014:

The main reasons for purchasing a new TV were the desire for a larger display panel (78%) and a higher resolution (66%). Nearly 30% – and thus the largest group among those surveyed – would like their next TV to have a screen diagonal between 42 and 47 inches (107 to 120 cm). In the previous year, the most popular screen diagonals had still been between 32 and 42 inches (81 to 107 cm).
The need for higher resolution goes along with larger screen sizes, and thus the interest in Ultra HD television display panels keeps growing. Further evidence for the fact that Ultra HD has arrived on the German market can be found in the sales figures for TVs: While, according to GfK – Gesellschaft für Konsumforschung, approximately 9,000 TVs with UHD displays had been sold by the end of 2013, a total of 36,000 was sold only between January and June 2014 [source: GfK Retail & Technology GmbH]. At the same time, TV manufacturers are steadily expanding their Ultra HD lines.

A key benefit for users and the most important selling point is the image quality of UHD displays. The dramatically enhanced resolution of the UHD technology, compared to Full HD, allows a significant improvement in the representation of details and in the degree of sharpness. Viewers perceive a better, more vibrant, more life-like image than on a Full HD display. This effect is enhanced by a curvature of the panel, which can be found mostly in the high-end segment of the display market. While the concave (“curved”) display panels presented at IFA 2013 were still prototypes, the new design, based on LCD technology, has been making inroads on the market since March 2014. Since, with a curved display, all areas of the frame are equidistant to the eye of a centrally positioned viewer, the image appears larger and richer in contrast than on “plane” flat display panels: a spatial effect is created, and the viewing experience is intensified. In addition to a significantly improved visual experience, UHD displays offer a practical benefit, too: Due to the high pixel density, the viewing distance can be cut in half, compared to HDTV. This allows not only people with small living rooms to enjoy the new viewing experience, but also enhances the immersion effect, thanks to the reduced distance to the screen and the curvature of the panel.

Under the roof of their European interest group, Digital Europe, device manufacturers are currently working on a family of “Ultra HD” logos that should be established on the market before the end of 2014, in order to provide retail and consumers with guidance.

2.1.1 UHD-1 Phase 1

By now, all major manufacturers are offering TVs which support the UHD-1 Phase 1 specification. These devices offer a variety of playback options for Ultra HD content: via HDMI and/or DisplayPort, playback of Ultra HD photo and video files, e.g. from flash drives, etc. In many cases, Internet sources – such as VoD services and free sources – are supported. Many of the latest UHDTV models are also equipped with built-in HEVC receivers.

2.1.2 UHD-1 Phase 2

Since Phase 2 of UHD-1 has not yet been specified, there are no suitable devices on the market yet.
2.2 Content Offering

2.2.1 Broadcast

At this point in time, there is no UHD broadcast content available in Germany for the following reasons:
On the one hand, it will take a while for the entire production chain – especially in the area of live coverage – to be technically converted to Ultra HD. After Sky Deutschland had kicked off this process at the end of 2012, it was not until late April 2014 that, for the first time, a complete live production could be realized in Ultra HD. The real-time encoding in the new H.265/HEVC standard had been the final building block, which had just become available. The complexity of the H.265/HEVC standard, which had only been endorsed less than a year earlier, requires an extremely high processing power and complex algorithms, especially for UHD content. For this reason, it was only possible for the first time in April 2014 to H.265/HEVC-encode a 2160p50 signal in real time.

Moreover, the H.265/HEVC decoder chip sets needed in UHD receivers and display panels to decode the signal, have only been available since the beginning of the year. For the live test in April 2014, they were supplied in the form of prototypes by various manufacturers for first-time testing with a live signal. It is now up to the manufacturers to develop them into production models for consumers. Since these devices will be used primarily for Pay-TV content, other aspects – such as encryption and other safety standards – will also play a role. For potential unencrypted UHD broadcasts, a few Ultra HD displays with built-in H.265/HEVC decoders are already available. They can access UHD demo content broadcast as tests by satellite operators Astra and Eutelsat.

2.2.2 IPTV

The development of IPTV-based UHD programming depends, first and foremost, on the available H.265/HEVC decoders. For IPTV, too, the launch of Ultra HD only makes economic sense if this new, efficient codec is used, regardless whether the content is a live broadcast or video on demand (VoD). Only by the end of 2014, final chip sets are expected that may serve as a basis for the hardware development of new receivers. Until such set-top boxes (STBs) will be on market, Full HD will remain the highest quality level of IPTV with current receivers.

The hassle-free streaming and immediate viewing of Ultra HD content in good quality will probably require an Internet connection with a data rate between 10 and 20 Mbit/s. Connections of this type are marketed by ISPs in many areas as DSL16 Plus, DSL 16000, and VDSL. Thanks to the latest transmission technology, more of these extremely powerful connections necessary for Ultra HD (more than 50 Mbit/s) will become available to consumers, thus complementing the cable operators’ options.
2.2.3 OTT

Parallel to the plans for broadcasting Ultra HD via cable, satellite, etc., the IP transmission via streaming will make an important contribution towards establishing Ultra HD. Netflix has announced it will offer its series, House of Cards, in several markets in Ultra HD resolution for streaming. This content, however, may only be viewed on select TVs. Samsung, Sony, and VoD service Maxdome might become pioneers in this area on the German market.

In mid-May 2014, a live event was streamed in UHD resolution via Internet for the first time. Owners of Samsung Ultra HD TVs were able to watch the opera, Nabucco, live from the Vienna State Opera via an app, using the new H.265/HEVC standard, which many of Samsung’s Ultra HD TVs already support.

In August 2014, Sony will introduce FMP-X5A, their 4K media player with an H.265/HEVC decoder, on the German market. It is intended to give buyers of previous Sony Ultra HD TVs a chance to stream appropriate Internet content to their TVs. According to the manufacturer, the device will support models KDL-84X9005 as well as KD-65X9005A and 55X9005A in streaming Ultra HD content. The player will be connected via HDMI. All Bravia TV models introduced by Sony in 2014 will not require this external media player, as they are already equipped with an integrated H.265/HEVC decoder.

VoD provider Maxdome is also planning a UHD offensive. According to an announcement made in May 2014, the company already plans to demonstrate UHD streaming via Internet for the first time at IFA 2014. From 2015, content in the new standard should be regularly available to Maxdome customers in their online video library.

Smart-TV specialist Vonetize is also planning to launch an Ultra HD streaming service for Smart TVs, implemented via Smart-TV app. The launch is intended to coincide with the market launch of Samsung’s latest model generation. For content, Vonetize is partnering with Hollywood studios Disney, Warner Bros., and Miramax, but the company has yet to release any information on the exact content of what will be offered in Ultra HD. It is remarkable, however, that they have announced to make their UHD streaming service available worldwide.

2.2.4 Other

It is anybody’s guess, at what time Ultra HD content will be available on Blu-ray as well. The Blu-ray Disc Association (BDA) has been working intensely and for some time now on a new standard for Blu-ray 4K, a work that is not necessarily accelerated by the large number of companies that have joined the BDA by now. Moreover, the BDA is very well aware of the fact that Blu-ray 4K is likely to be the last standard ever for a physical storage medium – reason enough to ensure that the standard to be defined will be as long-living and future-proof as possible.

By mid-2014, rumors intensified that the Blu-ray 4K might become available by year’s end. These speculations are also based on the assumption that H.265/HEVC will prevail over VP9 as the encoding standard. It seems to be certain, however, that the new 4K version of the Blu-ray will not be playable in existing Blu-ray players.
Some manufacturers try to bridge the waiting time for the Blu-ray 4K by offering Ultra HD content on hard drives. Samsung, for example, is selling a special 500-GB hard drive on which forty features have been prerecorded in a 3,840x2,160 pixel resolution. In addition to numerous documentaries, a few motion pictures, including the recent The Counselor by Ridley Scott, are also included.

### 3. Ultra HD – from Production to Reception

Both in the first edition of our White Book “Beyond HD”, published in August 2013, and in the updated edition of February 2014, we took an in-depth look at the Ultra HD chain from production to reception. Many of this information is still up to date, but in some aspects – especially regarding live production for Ultra HD – there have been recent developments and changes which we will address in the following chapters of this update.

#### 3.1 Content for Ultra HD

In chapter 2.2, we have already discussed the current range of content available in Ultra HD at length. It can be stated that the overall number of Ultra HD productions is growing and thus more and more content will become available in this high-resolution format. Nevertheless, at this early stage, choices are still quite limited.

##### 3.1.1 Scanning Existing Content for Ultra HD

To fill the increasing number of Ultra HD displays flooding the market with adequate content, over-the-top (OTT) options via Internet (cf. chapter 2.2.3) would be the first choice. For this form of delivery, the back catalogs of the major studios are being searched for motion pictures suitable for re-scanning in Ultra HD resolution. OTT providers and the manufacturers of consumer electronics with their media players have an advantage here over broadcasters, since they are able to target the growing population of Ultra HD displays directly.

In a further step, this avenue is also open to content with a higher dynamic range (cf. chapter 1.2.1), since only specific displays are addressed, which may offer such enhancements in the form of proprietary solutions. The motion pictures in question would undergo a so-called “tone mapping” process, in which suitable non-linear processing can enhance contrast. This is only possible with high-quality productions, since certain minimum standards for the signal-to-noise ratio (SNR) have to be observed.
3.1.2 Motion Picture Production for Ultra HD

Progress in feature-film production for Ultra HD is still rather sluggish. Even though 4K has almost become standard for many Hollywood productions, most of these films are not released in Ultra HD at first. The decision for using 4K in production is made only to secure future-proof source material, while the actual release continues to be in HD (= 2K). Due to high costs and immense demands on processing power, most computer-generated images (CGI) are still processed in 2K only, even for titles released in Ultra HD (4K).

In mid-July 2014, the independent Website, 4Kfilme.de, listed a total of 35 entries in its database under “Announced and available 4K movies and series." These include a number of titles offered by Sony Pictures Entertainment as "mastered in 4K" and thus "optimized for 4K TVs," including, for example, Taxi Driver from 1976, Ghost Busters (1984), and Godzilla (1998).

3.1.3 Live-Broadcast

Sky Deutschland has been the only broadcaster in Germany so far to organize several Ultra HD test productions, in order to gather experience in this new field. During the first half of 2014, the UHD live production chain was closed for the first time, including a working H.265/HEVC live encoder. 26 April 2014 marked a milestone: Werder Bremen at FC Bayern Munich, a match on game day 32 of the Bundesliga soccer season, provided the platform for the first end-to-end broadcast in Ultra HD at 50 frames per second. Brian Sullivan, C.E.O. of Sky Deutschland, was among the privileged viewers able to follow the live telecast from Munich’s Allianz Arena – captured by a total of six 4K cameras and four additional upscaled HD cameras – at Sky headquarters on several Ultra HD display panels. At the Playout Center, various H.265/HEVC encoders were used, and at the receiving end, Ultra HD receiver prototypes from several manufacturers were tested.

Sky Deutschland’s C.E.O. Brian Sullivan watched the first H.265/HEVC live broadcast in Ultra HD at 50 frames per second on 26 April 2014. On the right: A screen with the HD broadcast for comparison.
A similar test was repeated on 17 May 2014 with the “DFB Cup” soccer final at Berlin’s Olympic Stadium, where Borussia Dortmund met FC Bayern Munich. At this test, part of the broadcast was realized with a 10-bit color depth, rather than the customary 8 bits. In addition, the behavior of the live signal was observed while changing a variety of parameters, e.g. the bit rate or the type of contribution link (uncompressed vs. JPEG2000-compressed), in order to draw conclusions relevant to the further development of the H.265/HEVC encoder.

Apart from the variation of some of the technical settings, the two live productions in April and May also differed in production parameters. Partly due to the different location conditions, for example, different camera positions were taken in Munich and Berlin. Moreover, different lenses were used at the two events, in order to gather additional insights for the production process.

The two productions had in common that they were complete productions, i.e. in addition to a dedicated commentator for the Ultra HD broadcast, special UHD graphics were employed as well. Even though there has already been a certain crossover between the HD and the UHD production – e.g. by upscaling feeds from HD cameras to use them as part of the UHD signal and vice versa –, a simultaneous HD and UHD production of the same event, at this time, still requires two separate production setups and thus one OB vehicle each for HD and UHD. The goal of all future test productions therefore will be to streamline the workflow of the UHD production, but also to optimize the fusion with the HD production.

3.1.4 User-Generated Content

In the field of digital photography, cameras have long passed the megapixel threshold that allows consumers to generate still images in UHD resolution. In the course of 2014, an increasing number of digital motion-picture cameras (“camcorders”) has become available in the consumer and semi-professional segment that allow users to produce their own movies in Ultra HD. And Ultra HD has also reached the market of small, shock-proof “action cams.” However, these 4K cameras – just like some smartphones and tablet computers are often limited to a maximum of 30 frames per second.
3.2 Post-Production for Ultra HD

Leading manufacturers of video post-production software have integrated the option to process Ultra HD by now, eliminating the need to work with an HD intermediate.

Final Cut X and Adobe Premiere, for example, feature the import of video data from all common 4K cameras. For subsequent video editing in Ultra HD, the two codec formats, Sony XAVC and Apple ProRes, are available. A H.265/HEVC codec would also be desirable for the post-production software, but it is not yet available. XAVC-Files with 10 bit, 2160p50 have a data rate of approximately 430 Mbit/s. By employing an H.265/HEVC codec, this value might be reduced to a quarter. However, the conversion into H.265/HEVC files is already possible at this time by using external software solutions.

In spite of the large quantities of data generated by current codecs, some effects – such as subtitles, transitions, color correction/grading, and complex filters – can partially be applied in real time. In any case, editing Ultra HD files will require a very powerful computer.

Color grading for HDR (cf. chapter 1.2.1) will play an increasingly important role in post-production. For the color grading of a motion picture, the colorist should use the full color space and maximum luminance. This requires a high-quality display panel that can represent this high luminance and this high color gamut and dynamic range. Since the representation of color and brightness on consumer displays varies widely – due to the various display technologies –, the colorist should generate a variety of color adaptations of the color-graded original material, in order to emulate the behavior of different TVs on the market. Ideally, the HDR color grading should be a semi-automatic process that also generates an SDR version as a byproduct. It has to be ensured, however, that the colorist can intervene at any stage, in order to preserve artistic intent. Following the conclusion of the color-grading process, a format for exchange and filing (archive) is generated, containing all information for distribution or future processing.

3.3 Broadcast of Ultra HD

The real-time encoding in H.265/HEVC is complex and requires very powerful computer systems, making UHD live streams still a considerable challenge. Offline encoding, on the other hand, is simpler, since the encoding process aims at maximum quality in this case, rather than real-time operation.

Since April 2014, Ultra HD live production in H.265/HEVC is possible (cf. chapter 3.1.3), but under real-time conditions, first-generation H.265/HEVC encoders are still far from achieving the theoretical efficiency of the H.265/HEVC standard. The bit rates they can achieve today are thus no basis for commercially viable Ultra HD live programs.

For different applications, Ultra HD signals will have to be carried in different ways. The following table lists the protocols that would have to be supported, as well as the status of their standardization:
Regarding the broadcast of HDR data (cf. chapter 1.2.1), there are proposals for a downward-compatible HDR broadcast using a dual-layer approach, where the current SDR format forms the base layer, which existing receivers can decode. This base layer is supplemented by a second layer, the so-called “enhancement layer,” and potentially additional metadata to enable a reconstruction of the full HDR signal through combination.

### Table: Status quo of Ultra HD protocols

<table>
<thead>
<tr>
<th>Application</th>
<th>Transport Layer</th>
<th>Standard</th>
<th>Status</th>
<th>Limiting Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>broadcast (DTT, DTH, cable)</td>
<td>TS</td>
<td>MPEG-2 TS</td>
<td>international</td>
<td>DVB TS 101 154</td>
</tr>
<tr>
<td>broadcast (cable, IPTV)</td>
<td>TS via UDP</td>
<td>MPEG-2 TS/SMPT ST</td>
<td>international</td>
<td>DVB TS 101 154, TS 102 005</td>
</tr>
<tr>
<td>IP distribution (Qos, OTT)</td>
<td>MPEG-DASH</td>
<td>MPEG-DASH</td>
<td>international</td>
<td>DASH IF defines the guidelines for using H.265/HEVC with DASH</td>
</tr>
<tr>
<td>W3C (browser-based streaming)</td>
<td>MPEG-DASH-based</td>
<td>Media Source Extension/Encryption</td>
<td>published specification</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Schematic of a downward-compatible HDR broadcast

### 3.4 Receivers for Ultra HD

The launch of UHDTV will most likely be accomplished with the help of suitable set-top boxes (STBs), primarily for two reasons:

1. Just as in the case of the HDTV launch, Pay-TV providers will be the trailblazers for UHDTV. They are already using STBs on a grand scale, containing their user interface and the Conditional Access System (CAS). This gives them also great flexibility in supporting innovative systems in their early stages.

2. Since TVs with large display-panel diagonals are a major investment, they have life spans in the neighborhood of a decade. The implementation of new TV systems will thus take place only after a system has matured and been established on the market.
Initial broadcast tests via satellite have been conducted successfully (cf. chapter 3.1.3), using prototypes of UHD STBs. As in the introduction of HDTV, one of the key problems was the availability of chip sets for the new standardized encoding process, H.265/HEVC. All semiconductor manufacturers are working intensely on offering marketable products which also implement the necessary specifications of HDMI 2.0, in order to transmit the UHDTV video signal to the display panel in the best possible quality. The first prototypes had to compromise in this regard with HDMI 1.4b and a 4:2:0 subsampling. In addition, there are commercially driven discussions whether the video signals have to be displayed with 10 bit/sample, or whether 8 bit is sufficient. It is obvious that a lower sampling rate would keep the costs of displays lower, but it has been proven, on the other hand, that a 10-bit display leads to a more effective encoding, which would then be advantageous for the transmission.

The High-Definition Multimedia Interface (HDMI) serves the transmission of video and audio signals between receiving units (e.g. STBs), playback devices (e.g. Blu-ray players), and displays. Since the introduction of the new features for HDMI 2.0 at IFA 2013 in Berlin, a pixel resolution of 3,840x2,160 can now be carried at a frame rate of 50 and/or 60 fps, an essential prerequisite for the introduction of UHDTV, of course. To realize the ideal of some broadcasters, who would like to transmit images at higher frame rates (e.g. 100 or 120 fps), however, the standard would have to be amended once more. The following table shows various resolutions with the corresponding color subsamplings supported by HDMI 2.0.

<table>
<thead>
<tr>
<th>Resolution</th>
<th>8 bit</th>
<th>10 bit</th>
<th>12 bit</th>
<th>16 bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>2160@24</td>
<td>RGB</td>
<td>RGB</td>
<td>RGB</td>
<td>RGB</td>
</tr>
<tr>
<td>2160@25</td>
<td>RGB</td>
<td>RGB</td>
<td>RGB</td>
<td>RGB</td>
</tr>
<tr>
<td>2160@30</td>
<td>RGB</td>
<td>RGB</td>
<td>RGB</td>
<td>RGB</td>
</tr>
<tr>
<td>2160@50</td>
<td>RGB</td>
<td>RGB</td>
<td>RGB</td>
<td>RGB</td>
</tr>
<tr>
<td>2160@60TS</td>
<td>RGB</td>
<td>RGB</td>
<td>RGB</td>
<td>RGB</td>
</tr>
</tbody>
</table>

Another aspect to be considered is copy protection at the HDMI interface. So far, High-bandwidth Digital Content Protection (HDCP) in its version 1.4 has been used worldwide on HDMI, but this process is no longer considered safe, since it was hacked. For content of even higher quality – such as UHDTV –, the Hollywood majors have therefore demanded the successor system, HDCP 2.2, to be implemented, in order to ensure adequate content protection against illegal copying. The discussion when and where this might be implemented is currently underway. It is obvious that the introduction of a new broadcast system would offer an excellent opportunity to introduce this new copy-protection system as well.
There is a general consensus that UHDTV will have to offer a significant improvement in image quality, compared to today’s HDTV, in order to find acceptance on the market. Increasing the image's spatial resolution along with a further increase in display diagonals is not the only parameter. A higher frame rate (cf. chapter 1.2.2), an extended color gamut (cf. chapter 1.2.4), and a higher dynamic range (cf. chapter 1.2.1) will be additional criteria. There have been a few early demonstration, but some time will probably pass until the devices are ready to go into production. One major dilemma is already predictable: On the one hand, the goal is to emulate reality as close as possible with a high dynamic range – on the other hand, politicians expect a sensible and economical use of energy in consumer electronics – seemingly contradictory demands, at first glance. Some developments have been initiated, however, that should further lower energy consumption.

However, in the end, it makes only sense to introduce all the extensions and expansions discussed above on the consumer side, if they have been implemented across the entire chain from production and broadcast to the receiver and display panel. It will still take a while to achieve standardization on all levels.

For the major shows (IFA, IBC) in the fall of 2013, the first prototypes of UHDTV set-top boxes were introduced, but the technical parameters of these STBs were still dependent on available chip sets, for which specifications had not been finalized at the time. The first chip sets supporting 50/60 fps and 10 bit were ready for production just before the start of the FIFA soccer World Cup, and the first UHDTV STBs have been delivered to Pay-TV operators, such as Tata Sky in India or Oi in Brazil.

3.5 Displays for Ultra HD

From a technical point of view, display panels with a Ultra HD pixel resolution can be produced using existing LCD and OLED technology. LCD models are by far more numerous, since their production – even for large diagonals, whether plane or concave (“curved”) – is well understood. LCD backlight technology also allows the production of panels with a higher peak brightness and dynamic range – a first step in the direction of true HDR (cf. chapter 1.2.1). OLED is a technology of the future, but there are still a few manufacturing problems to be solved, before these devices will be able to compete with LCD on the open market.

Since IFA 2013, the major TV manufacturers have expanded their product lines with numerous Ultra HD models. By now, consumers are able to choose from TVs in all sizes up to 280 centimeters (110") in diagonal and with a wide variety of options. Due to the value-for-money aspect, these TVs almost exclusively feature LCD display panels. The first displays with an improved dynamic range have also reached the market. The broadening of the manufacturers’ ranges also means that UHD is no longer a topic just for the premium segment (cf. chapter 2.1). While the first models available on the market were exclusively placed in the upmarket segment, UHDTV has by now reached the upper middle class and has become affordable for a wide consumer base. One manufacturer has announced that all their TV models marketed from IFA 2014 onward will feature UHD resolution.
Some manufacturers offer the option to upgrade their TVs by exchanging external boxes, allowing owners to easily keep pace with new developments in television technology without the need to exchange the entire television set.

Until the broadcast of UHDTV signals via satellite or Internet streaming becomes available in Germany, users have to rely on device-based upscaling of HD material. All TV manufacturers have integrated appropriate technologies into their displays, which convert images in lower resolution into UHD and can thus display them over the full screen. Such "upscalers" may vary widely in quality – depending on their price, of course –, requiring consumers to take a close look when making a purchase. In the end, the best possible viewing experience for the consumer should be the key criterion.

**Glossary**

**HDR High Dynamic Range**
For the quantization of the luminance signal and the color difference signals, 8-bit depths (SDR) have been typical so far, but they only permit the display of 256 different degrees of contrast. HDR will allow a significantly larger number (512 at 10 bit or 1,024 at 12 bit).

**HFR High Frame Rate**
A frame rate higher than the – so far – customary rate of 50 Hertz (Hz), or frames per second (fps). For Ultra HD, 100 or 150 Hz are planned.

**SDR Standard Dynamic Range**
The contrast (dynamic range) of a television image at a bit depth of 8 bit.
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