Beyond HDTV Technology 11 h 58 Abstract - Many broadcasters are still in the phase of implementing HDTV (High-Definition Television) for all regular services and this activity will set the main focus in production and distribution for the upcoming years. However, the consumer and professional industries, are already promoting technologies beyond the current HDTV formats used in the	Công nghệ hậu HDTV Tóm tắt-Nhiều đài truyền hình vẫn còn trong giai đoạn triển khai HDTV (Truyền hình độ sắc nét cao) cho tất cả các dịch vụ thường kỳ và hoạt động này sẽ đặt trọng tâm chính vào sản xuất và phân phối trong những năm sắp tới. Tuy nhiên, người tiêu dùng và các công ty chuyên nghiệp đã tiến hành xúc tiến công nghệ tiên tiến hơn định dạng HDTV hiện tại được sử dụng trong lĩnh

broadcast domain so this paper presents an overview of existing technologies. Very soon, new consumer and professional products will enter the market with resolutions clearly beyond that of current HDTV. The ultimate aim is to give the consumer a significantly enhanced viewing experience. Broadcasters may wish to choose a future proof format and may even be forced by competition to change their format. While high frame rates offer better temporal resolution, which is good for sports and other content with high motion scenes, image formats with higher spatial resolution improve the imagery for genres such as movies, drama and documentary. Beyond HDTV, Japan's Broadcasting Corporation NHK (Nippon Hoso Kyokai) has developed a new TV standard that will be a major advance in television broadcasting and that will create an entirely new environment, television shows. This is the next natural step forward in display technology, offering consumers an incredibly immersive viewing experience with stunning new levels of image quality. There are several up to date terms for this new standard, such as Quad HD (High Definition), UHD (Ultra High Definition), 4K (4000 horizontal pixels) or 4K UHD television.
Keywords - NHK; Quad HD; UHD; 4K; 4K UHD television

vực phát sóng, vì vậy, bài báo này trình bày tổng quan về các công nghệ hiện tại. Các khách hàng mới và các sản phẩm chuyên nghiệp sẽ nhanh chóng tham gia vào thị trường với độ phân giải tốt hơn độ phân giải của HDTV hiện tại. Mục đích cuối cùng là cung cấp cho khách hàng trải nghiệm hình ảnh tốt hơn. Các đài truyền hình có thể sẽ chọn một định dạng thử nghiệm trong tương lai hoặc thậm chí phải cạnh tranh để thay đổi định dạng của họ. Trong khi tốc độ khung cao cho khả năng phân giải thời gian tốt hơn, thích hợp với các chương trình thể thao và nội dung khác có khung hình chuyển động tốc độ cao, các định dạng ảnh với độ phân giải không gian cao cải thiện chất lượng hình ảnh thuộc các thể loại như phim ảnh, phim truyền hình và phim tài liệu. Vượt qua HDTV, tập đoàn truyền hình Nhật Bản NHK (Nippon Hoso Kyokai) đã phát triển một tiêu chuẩn TV mới sẽ trở thành một bước tiến quan trọng trong công nghệ truyền hình và sẽ tạo ra những chương trình tivi môi trường hoàn toàn mới. Đây là một bước tự nhiên nhằm hướng về công nghệ hiển thị, mang đến cho người tiêu dùng trải nghiệm xem như thật cùng với chất lượng hình ảnh tuyệt vời. Có một số thuật ngữ mới đối với tiêu chuẩn này, chẳng hạn như HD Quad (độ nét cao), UHD (độ nét siêu cao), 4K (4000 pixel ngang) hoặc tivi 4K UHD.

INTRODUCTION

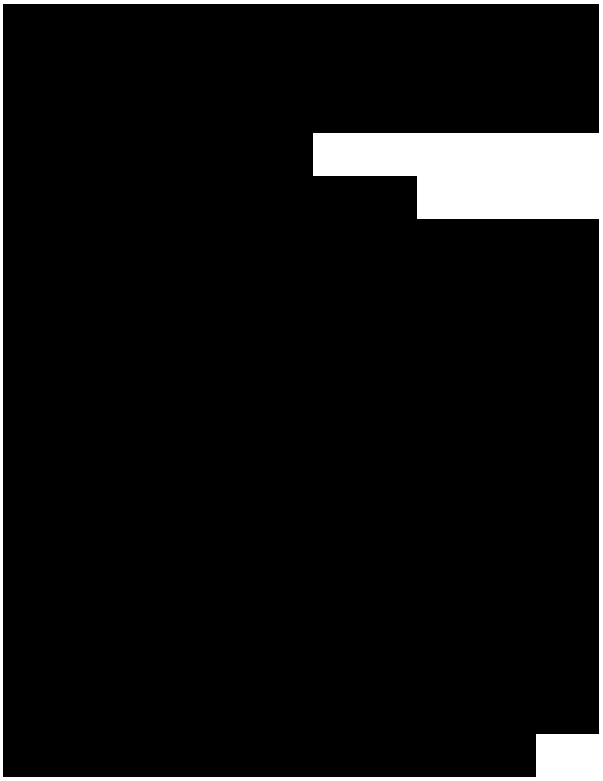
Here is a description of new technology that is currently being developed by NHK that goes beyond

[redacted]

the current HDTV experience. Parameter values for these new television systems for production and international program exchange are defined by ITU-R BT.2020 (International Telecommunication Union Recommendation) [1]. Main characteristic of this new standard is that it has four times higher resolution and it has a wider color gamut than 1080p HDTV. Because of many different terms for this new standard, on October 18, 2012 the Consumer Electronics Association [2] announced, that "Ultra High-Definition", or "Ultra HD", would be used for displays that have an aspect ratio of at least 16:9 and at least one digital input capable of carrying and presenting native video at a minimum resolution of 3,840 x 2,160 pixels. On the other side, the consumer and professional industries use the term 4K for UHD consumer products. 4K refers to high definition resolutions: 3840 x 2160 pixels for TV broadcasting (8.3 megapixels), and 4096 x 2160 pixels (8.8 megapixels) in commercial digital cinema projection. Displays will have an aspect ratio with width to height of at least 16 x 9. Because of that, for the purpose of this paper it is used the term 4K UHD when it talks about a TV broadcast standard and the term 4K for a digital cinema. Fig. 1 shows main characteristics of 4K UHD standard. The diagram of the CIE 1931 (International Commission on Illumination) color space shows the 4K UHD color space in the outer triangle and the HDTV color space in the inner triangle as it is shown in Fig. 1 (a). Fig. 1 (b) shows the evolution of

image formats from SD (Standard Definition) resolution, via HDTV and 4K UHD to the 4K resolution [4]. In this picture we can see a difference between 4K UHD and 4K resolution.

a) Colour gamut diagram [3] b) Evolution from SD to 4K resolution [4] Figure 1. Main characteristics of 4K UHD standard



II. HISTORY OF 4K UHD

At NHK, research of new video systems beyond HDTV began in the mid-1990s, with the commencement of work on a UHD camera. One envisioned application for this research was the creation of HDTV programs and advanced HDTV services. Later, they clearly set the goal of formulating a new media format to surpass HDTV specifications, and they developed first UHD prototype system. This system was consisted of a camera, disk recorder, and projection display [5].

III. UHD EQUIPMENT

For 4K UHD live production, it is necessary to have equipment to capture, process, compress, store, distribute and display 4K UHD signal. Fig. 2 (a) shows the 4K UHD OB van (Outside Broadcasting), and Fig. 2 (b) shows the 4K UHD control room in the OB van.

a) OB van for 4K UHD [6]

b) The control room in OB van [7]

Figure 2. Live production

Capturing consists of many remotely controlled cameras. Uncompressed signal from the camera is mixed and processed in the video switcher and then compressed so that it can be transmitted or stored on a Blu-ray

disc, memory card or storage disc. Compression is enabled with a new compression algorithm, and 4K UHD signals will be transmitted via terrestrial DVB-T2 (Digital Video Broadcasting - Terrestrial Second Generation), or satellite DVB-S2 (Digital Video Broadcasting - Satellite Second Generation) system. These signals will be seen on 4K UHD LCD or OLED (Organic Light-Emitting Diode) televisions.

IV. TYPES OF 4K UHD CAMERAS

In the following section will be described three types of 4K UHD cameras. The first type uses a beam-splitting prism and three image-sensor chips, just like a typical studio or truck camera, as it is shown in Fig. 3 (a). Prior to Bayer's invention 4K UHD camera had used three HD-resolution chips with the green offset from the red and blue. These achieve the impressive feat of recording the precise location of each color of light without using the color filters. However, that set-up was too large and expensive (it costs three times more than the camera with one sensor chip), to be used by the masses. Also there have been four-chip cameras, as it is shown in Fig. 3 (b). Idea for a 4K UHD live camera system, a camera system with a 4 way optical beam splitter is described in a SMPTE (Society of Motion Picture and Television Engineers) report, published in 2004. 4 way beams splitting is not new, but the application is. The 4 way beam splitter splits the incoming light into G1, G2, R, and B. The green sensors are mounted on the prism with a diagonal half pixel offset.

In this way the optical block creates a kind of color filter layout and after interpolation it gets 3840x2160 pixels in the Y channel. In Cr and Cb it has 1920x1080. The result is a 4:1:1 Y, Cr, Cb 4K camera. The advantage is that broadcast companies can still use the 2/3 inch optical system [9].

a) Prism for three chips [8]
b) Prism for four chips [9]
Figure 3. Two types of beam-splitting prisms

Other 4K UHD cameras have single chip overlay with color filters (the Bayer pattern). Fig. 4 shows the difference between cameras with four chips and cameras with one chip. In a filtered single-chip or four-chip camera, digital sensors capture images using arrays of light-gathering wells or "photosites." When the exposure starts, these are uncovered to collect photons of light, then, when the exposure ends, these are read as an electrical signal, quantified and stored as values in a digital file. To assess color, photosites typically also use filters to ensure that only one color is stored at a time. An image captured with a Bayer-filter camera is known as a Bayer

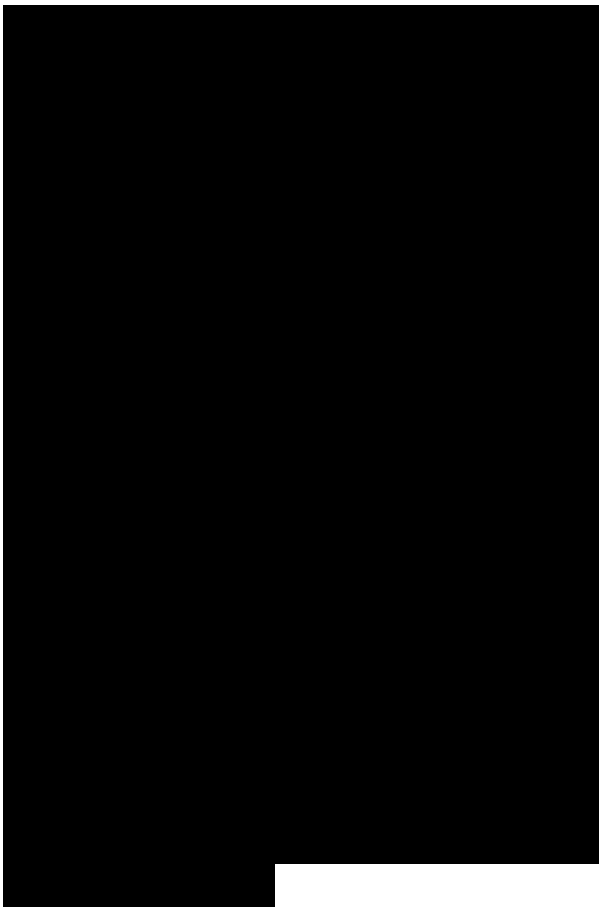


Figure 4. Four chip and single chip color imaging [10]

pattern image. As it is shown in Fig. 5, a Bayer's array is an array of alternating three color filters that sample only one color band at each pixel location. The three color filters in Bayer's array are needed to create color from the grayscale image

information that is captured by the imaging chip. Bayer pattern is the most popular color filter array, which features blue and red filters at alternating pixel locations in the horizontal and vertical directions, and green filters organized at the remaining locations. This pattern results in half of the image resolution being dedicated to accurate measurement of the green color band. The peak sensitivity of the human visual system lies in the medium wavelengths, justifying the extra green sampling. Because each pixel now has only one color sampled, a demosaicing algorithm (also called “debayer”) must be employed to recover the missing information and produce full color pixels [11].

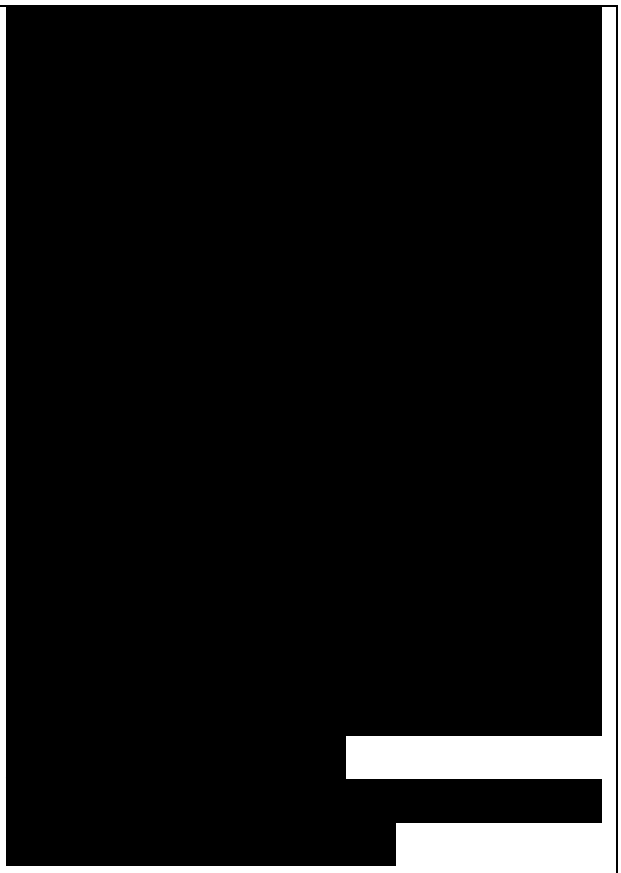
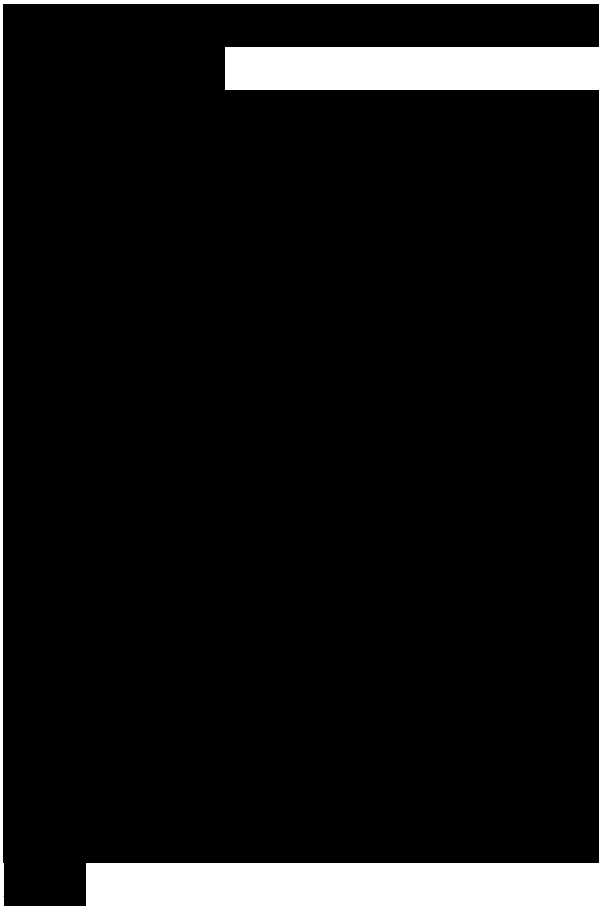


Figure 5. Three color filters in Bayer's array [11]



Bayer "demosaicing" is the process of translating this Bayer array of primary colors into a final image which contains full color information at each pixel. Several algorithms exist for this purpose, ranging from simple linear interpolators to high- end nonlinear. The simplest of all interpolation algorithms is nearest neighbour interpolation and it is shown in Fig. 6. Using a 2x2 neighbourhood from the Bayer pattern color filter array, missing pixel values are interpolated by simply adopting the nearest sampled value. The sampled blue and red values in this 2x2 neighbourhood are used at the three remaining locations. The sampled green values can be moved in either a vertical or horizontal direction to fill in the pixels without green information [12].

Figure 6. Bayer demosaicing [12]

This method introduces significant color errors, especially along the edges, but it is useful for understanding how the Bayer mosaic works. Note: all digital cameras do not use a Bayer array. There are many demosaicing algorithms and we can say that the demosaicing is not a trivial problem, because it has to interpolate a lot of information, and that there are many solutions to process mosaicked images. However Bayer demosaicing is by far the most common setup. Fig. 7 (a) shows one 4K UHD broadcast camera, and Fig. 7 (b) shows one consumer camcorder.

V. COMPRESSION

The compression means that we need to compress resolution of 8 million pixels of one image to more than hundred times less resolution , and, of course, at the end of the video chain, the possibility of watching video signal on even larger screens without some kind of noticeable loss in image resolution. High Efficiency Video Coding (HEVC) is a new standard for video compression developed by the ISO (International Organization for Standardization) and ITU-T. The Moving Picture Experts Group (MPEG) and Video Coding Experts Group (VCEG) set up a Joint Collaborative Team on Video Coding (JCT-VC) to create the new standard. HEVC is a joint publication of ISO/IEC (International Electrotechnical Commission), and ITU-T, formally known as ISO/IEC 23008¬2 and ITU-T Recommendation H.265. The new HEVC standard received first stage approval in January 2013. Additional work is

planned to extend the standard to support several additional application scenarios, including extended- range uses with enhanced precision and color format support, scalable video coding, and 3-D/stereo/multiview video coding
[14].

A. HEVC Application

HEVC has been designed to address essentially all existing applications of H.264/MPEG-4 AVC and to particularly focus on two key issues: increased video resolution and increased use of parallel processing architectures. The video coding layer of HEVC employs the same hybrid approach (inter/intrapicture prediction and 2-D transform coding) used in all video compression standards since H.261 [14]. HEVC achieves improved coding efficiency by introducing additional tools to exploit spatial and temporal correlations. Specifically, HEVC incorporates enhanced motion-compensated filtering, multiple coding block sizes and expanded loop filters, including de¬blocking, sample adaptive offset and an adaptive loop filter.

Some of the key improvements in HEVC are due to the use of larger block sizes, making the standard well-suited for 4K UHD. The larger block sizes enable more efficient coding of large images, especially of regions with few changes in the picture content. Improved intra frame prediction enables better prediction of pixels by exploiting redundancy within the current frame. The proposed tools offer more direction predictions than H.264/MPEG-4 AVC, and more sophisticated way of

predicting and coding the intra mode selected. HEVC also directly addresses the banding problem that can be seen with H.264/MPEG-4 AVC, where contouring artefacts appear when coding flat or smooth image backgrounds. An internal increase in precision (greater bit depth) adds greater accuracy to internal calculations. These extra bits help to prevent the banding. In addition to these benefits, HEVC offers support for interlaced video so that content providers can efficiently compress, store and transmit decades of legacy content. In the future, HEVC may include support for multi-view video coding or stereo 3-D video, combined with scalable video coding, enabling a video stream, sequence or image to be represented in multiple ways and multiple formats. This ensures that content can be prepared in different resolutions, frame or bit rates, for viewing on any device, such as an HDTV or smartphone, while retaining a high level of coding efficiency
[15].

B. Benefits of HEVC

HEVC promises to improve upon the current compression standard H.264/MPEG-4 AVC. Using HEVC, broadcasters can reduce the data rate needed for high-quality video coding by approximately 50 percent, enabling them to deploy higher quality OTT (Over The Top) video services using the same amount of bandwidth, or half the bandwidth at the same quality as it is shown in Fig. 8. The potential for HEVC spans a wide gamut of applications, including home and digital cinema, surveillance, broadcast,

videoconferencing, mobile streaming, video on demand (VOD), video storage and playback. HEVC has the ability to significantly affect next-generation HDTV displays and content capture systems that feature progressive scanned frame rates and display resolutions up to 4K UHD. Through HEVC, content providers can more efficiently deliver high-quality 4K UHD content using today's networks.

Another application for HEVC is a fixed-point contribution environment, such as news gathering, live events, sports and concerts, where bandwidth is typically restricted. By replacing today's MPEG -2 or H.264/MPEG-4 AVC equipment with HEVC technology, broadcasters can reduce the bit rate and cost-effectively deliver more content at a higher quality. Possibly the biggest application for HEVC is OTT video delivery. Video is expected to represent more than 50 percent of Internet traffic by 2016, so a reduction of 50 percent of the video bandwidth will have a tremendous impact on the video experience and on the video business. Possibly the biggest application for HEVC is OTT video delivery [15]. Note that except the HEVC codec, some professional industry uses some another codecs for compression.

VI. PROCESSING

Central device in any studio or OB van is the video switcher. Video signals from all video sources are coming into the video switcher. Inside the video switcher, these signals are mixed and processed. The final signal from the video switcher is distributed for further processing or it is

compressed and prepared for transmission or storing. Fig. 9 shows the 4K UHD video switcher for live and post production.

Figure 9. 4K UHD video switcher [18]

VII. STORAGE

Consumer access to 4K UHD content could soon be improved, following the Blu-ray Disc Association announcement that it has created a task force within its member companies to investigate extending the Blu-ray spec to deliver 4K UHD movie content. Blu-ray has disc capacities of 25GB and 50GB so storage should not be a barrier to movie companies wanting to take advantage of the new Blu-ray spec. Fig. 10 (a) shows a 4K UHD Blu-ray player, and Fig. 10 (b) shows SR memory card with storage capacity up to 1 Terabyte which is capable of 4K production. There is also the REDRAY 4K Cinema Player, with an internal hard drive and networking capability, so content can be played from local storage or streamed.

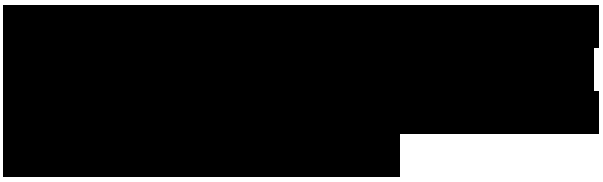
a) Blu-ray player [16] b) SR Memory Card [17]

Figure 10. Storage

These new generation professional video recorders supports 4:2:2 and 4:4:4 recording even at HD resolutions, high-quality debayering, and real time scaling from 4K UHD to HD HDMI output allows connection to HD consumer monitors. HD-SDI output provides professional grade connectivity to high-end monitors [19]. Fig. 11 (a) shows professional

4K UHD storage device which enables recording with camera, and Fig. 11 (b) shows one storage device for working in studio. They are Multi-Function Solid State Recorders and they are ideal for broadcast, cinema, post production and events industry.

a) Enables recording with camera [19]
b) Working in studio [20]
Figure 11. The Next Generation Professional 4K UHD storage devices



VIII. TRANSMISSION

It is possible to transmit 4K UHD signals via terrestrial DVB-T2, satellite DVB-S2 or cable system. Fig. 12 shows the possibility of the next-generation equipment for distribution and broadcasting 4K UHD programs. Within Asia, for example, only Japan and South Korea have demonstrated or indicated plans of testing 4K UHD broadcasting. Meanwhile in Europe, Eutelsat Communications launched the first dedicated demonstration 4K UHD channel in the region on Jan. 8, 2013. The broadcast, delivered via satellite, has a resolution of 3840x2160 at 50fps and transmitted at 40Mbps [25]. Abertis Telecom ran a test of 4K UHD DTT at the Mobile World Congress in Barcelona in February 25 to 28. The Spanish company shows the DVB-T2 standard suitable for 4K UHD and mobility devices. It was working with the European Broadcasting Union (EBU), the Polytechnic University of Madrid, La Salle, Sony and producer Lapospo [26].

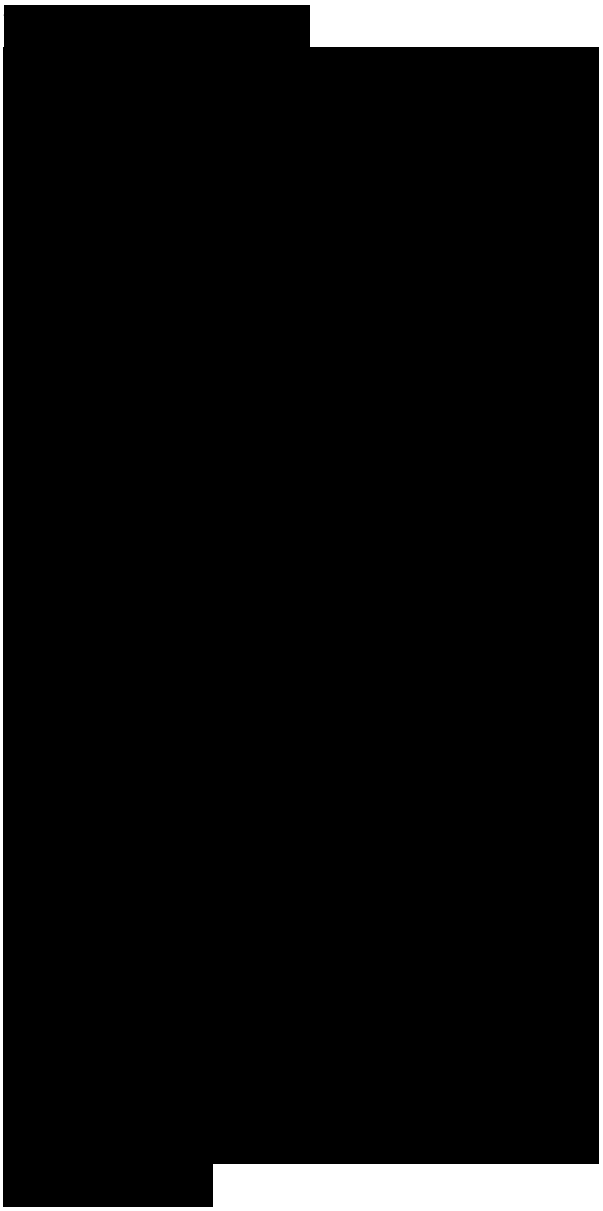


Figure 12. DTV broadcasting of 4K UHDTV program [21]

It is expected to use a more efficient HEVC codec. The predicted bit rate required for 4K UHD using HEVC will be a number in the twenties of megabits.

IX. 4K UHD TV DISPLAYS AND OTHER PRODUCTS

4K UHD television could be in our homes much sooner than some might have thought. Fig. 13 (a) shows the 4K UHD OLED television. The world's first and largest 56" OLED TV achieves 4K UHD resolution was shown this year in

a) 4K UHD OLED television[22]
b) 4K PlayStation [23]

Figure 13. 4K Products

X. CONCLUSION

4K UHD television is here to stay whether we like it or not (we do!). The 4K revolution has begun with the new advanced cameras and the big Hollywood studios who switched to digital acquisition and file based delivery. To this end it is very encouraging to see that Disney, Fox, Paramount, Sony Pictures, Universal and Warner Bros, are pushing hard for 4K to become the new industry standard. In January 2013 Sony, LG, Panasonic and JVC all introduced 4K UHD home display technologies at the CES. 4K UHD standard has high demands on bandwidth, storage and processing, that means that engineers at the professional broadcast industry have many challenges, but the fact is that it is not as technically complex as 3D. The Blu-ray format is an ideal 4K and 4K UHD delivery platform as it is bound to evolve with larger capacity discs and faster transfer speeds. The HDMI V1.4 is already capable of

handling 4K UHD images. The HEVC standard has the potential to have a revolutionary impact on OTT video delivery, as it will dramatically reduce the bandwidth compared to existing H.264/MPEG-4 AVC-based delivery systems. Video can be delivered at a higher quality or at the same quality using a lower bit rate. Finally, this is not the end of the researching and development of broadcast technologies. New 8K UHD video standard is knocking on the door.