IMPLEMENTATION OF 4K ULTRA HIGH DEFINITION TELEVISION 1 (UHDTV1) STANDARD

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Abstract: This article is introducing new digital 4K TV or UHDTV1 standard as a part of the Ultra High Definition Television (UHDTV) solutions for public and household applications. Here is also discussed the newest video coding standard known as High Efficiency Video Coding (HEVC) important for improvement of video quality.

Keywords: UHDTV, 4K UHDTV1, HEVC, 8K UHDTV2, HEVC/H.265, AVC/H.264, MPEG-2

I. INTRODUCTION

As stated above, 4K Ultra HDTV (UHDTV) is one of the two Ultra HDTV formats, while the second newest UHDTV format is coming on the way known as 8K TV or UHDTV2 standard. Technically speaking, 4K is not the same as 4K UHDTV standard. Consumer 4K resolution of 3840x2160 (at a 16:9, or 1.78:1 aspect ratio) differs from the industry standard of 4096x2160 (at a 1.9:1 aspect ratio), namely there is small difference in size of TV display. Thus, the standalone term "4K" was originally used to describe digital cinema (4096×2160 px). Since digital cinema resolution is not available in a consumer television, the term "Ultra HD" (3840×2160 px) and "4K UHDTV" (4096x2160) were invented. However, it has to be noticed that the slight reduction in 4K UHDTV resolutions is to achieve a 16×9 aspect ratio. In **Figure 1** are shown values of SDTV, Full HDTV, Ultra HDTV and 4H UHDTV standard. Therefore, is important to find out the difference between all current definitions and new standards.

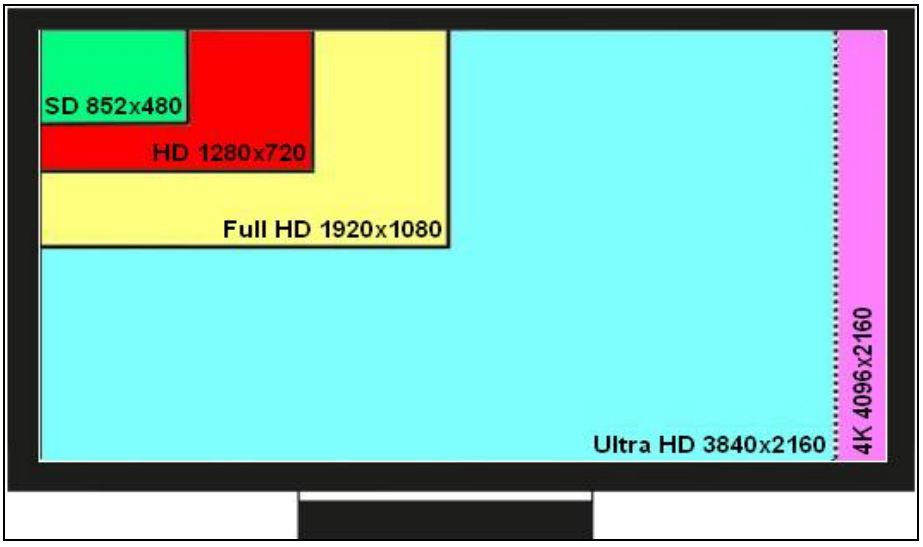

Figure 1. Comparisons of SD, HD, Full HD, Ultra HD and 4K Standards – Courtesy of Brochure: by R&S [1]

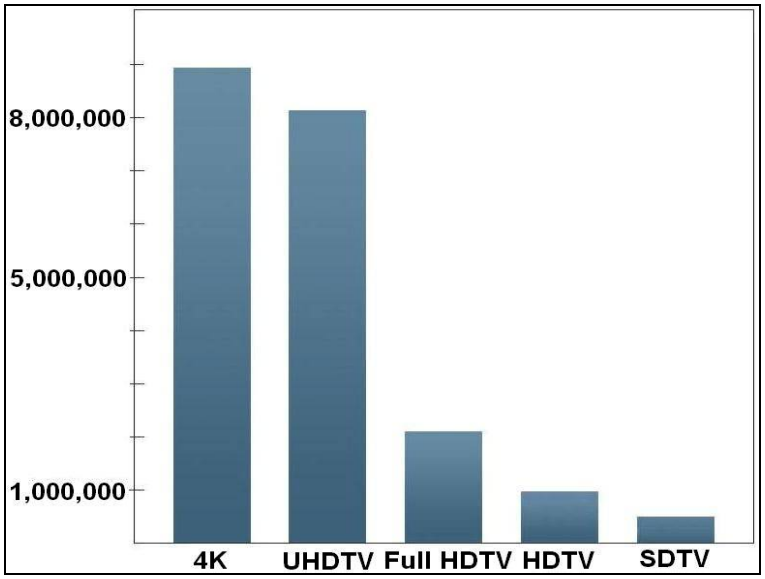

Figure 2. Total Number of Pixels per Frame **–** Courtesy of Brochure: by Paul's [2]

II. ADVANTAGES OF 4K STANDARD

The advantage of the 4K gives exactly four times the resolution of Full HDTV, which produces a magnificent image when viewed in person. The consumers will be doing themselves a great injustice if they try to gauge the clarity of a 4K screen using their computer or current Full HDTV, so they will not experience anything near the actual quality of 4K Ultra HDTVD. In the first stage of development, 4K Ultra HDTV displays are available today from several manufacturers, including Sony, Samsung and Seiki. Other known TV producers, like Sharp, Toshiba, TCL, and HiSense began offering 4K Ultra HDTV's from the end of 2013, which products are spread worldwide.

The new UHDTV technology is knocking on the door with the introduction of 4K and HEVC solutions. This is the new standard of video quality that will boast resolutions far beyond HDTV and catapult television into what will come to visualize as Ultra High Definition TV (UHDTV). This technology will be another iteration of Three Dimensional (3D) space and will parallel the impact UHDTV had on HDTV in Markets ranging from broadcast, to cable TV, to mobile devices and cellular phones. Broadcasters and content or service providers are in a heated race to provide this new technology. The major challenge and hurdle that everyone is tripping over is the bandwidth that will be required to deliver such media. To make any kind of hypothesis as to how this will pan out, it is necessary to dig deeper into what HEVC and 4K standard actually are. Namely, let's begin by first understanding the differences between HEVC and 4K. While some may use them interchangeably, they are different and should not be confused.

On the other hand, if somebody is learning how to get Smart TV, 3D TV, LED TV and other modern TV terms straight, it will be necessary to understand new terms floating around, that UHDTV stands for 4K and 8K, which refers to the different resolution. Thus, UHDTV with its two standards is one of the latest features in new high-end TV standards and different displays. In order to fully understand what 4K is and why it's an improvement over standard definition and high definition, everybody must first understand how resolution works. Digital pictures, like the one on any television, computer monitor or digital camera, are made up of pixels. Each pixel contains three sub-pixels, one red, one blue and one green. A picture is created by turning these sub-pixels on and off and by adjusting their brightness. In **Figure 2** is presented total number of pixels per frame for 5 standards.

Figure 3. Prototype of Sony 4K TV Standards Currently with high Resolution – Courtesy of Brochure: by BanehDigital [3]

More pixels will result in better detail and sharper images on the screen. Different resolutions you may come across are:

- Standard Definition (SD) of 480px is 852 pixels long and 480 pixels wide, for a total of 408,960 pixels.
- High Definition (HD) of 720px is 1280 pixels wide by 720 pixels long, for a total of 921,600 pixels. This has more than twice as many pixels as SDTV.
- Full HD of 1080px is 1920 pixels wide and 1080 pixels long for a total of 2,073,600 pixels. This has more than twice times as many pixels as HDTV.
- Ultra HD definition of 2160px is 3840 pixels wide and 2160 pixels long for a total of 8,294,400 pixels. This has more than four times as many pixels as a full HDTV.
- 4K refers to a resolution that is approximately 4K by 2K. In a TV, this is generally 4096 pixels long by 2160 pixels wide, for a total of 8,847,360 pixels. In cinema this may vary slightly, however 4K resolution has more than one time as many pixels as basic UHDTV.
- 8K is 7680 pixels long by 4329 pixels wide, for a total of 33,177,600 pixels. It is worth noting that while this technology does exist, it will be quite a few years before it is widely available for use. Most cameras are not even capable of capturing footage in this format yet, because most films are shot in 4K or 5K standard [1, 2, 3, 4].

III. BENEFIST AND COST OF 4K STANDARD

Ultra high definition is a new resolution with more than 8 million pixels, which is over 6 million more pixels than a Full HD 1080p TV. In fact, people will one day look back on regular HDTV and wonder how they ever watched such a low resolution image. According to the International Telecom Union (ITU) regulations and recommendations UHDTV standard includes two formats, a “4K” format named UHDTV1 and an “8K” format, UHDTV2. The UHDTV1 standard provides a resolution that is 4 times the resolution of Full HD (1920x1080) for TV, while true 4K is effectively a standard for digital cinema with 4096x2160 resolutions. The Ultra HDTV resolutions will be delivered to the home as UHDTV at an astounding 3840x2160 lines (8.3 megapixels). The final iteration of the UHDTV standard is UHDTV2, which resolution is 7680 pixels × 4320 lines (33.2 megapixels) and is considered for future deliveries.

Figure 4. Prototype of Sharp 4K UHDTV Standard – Courtesy of Brochure: by Paul's [1]

Thus, a 4K resolution results in a crisp, clear, and lifelike image, which will enhance any viewer's TV-watching experience. For instance, people with large screens and passive 3D will notice the biggest difference.

In August 2012, the Consumer Electronics Association (CEA) introduced the term Ultra High Definition, partly defined as resolutions of "at least 3,840x2,160 pixels". The idea was to replace the term 4K, thus the name of CEA lasted less than a day, as Sony then announced it was going to call the technology 4K Ultra High Definition, which prototype is illustrated in **Figure 3**. This is the term now used by most other TV manufacturers too, which seem interested in covering all the buzzword bases at the expense of brevity. In practice, customers will often see UHD used interchangeably with 4K, whether describing TV, source devices, accessories or broadcasting content. Thus, at CNET say "4K" instead of "UHD" almost exclusively, so many producers and vendors strongly agree.

The latest in a line of broadcast and media resolution, 4K is due to replace 1080p as the highest-resolution signal available for in-home movies and television. With the arrival of 4K there are four main resolution standards for use in the home: standard definition (480p/540p), high definition (720p), full high definition (1080i/p) and 4K or ultra high definition (2160p). When customer supplies a big screen, he has larger pixels to fill the space. Because a screen with a 4K resolution has more than four times as many pixels as one with a Full HDTV resolution, buyer can have a larger screen size without sacrificing picture quality. Another area that benefits from 4K technology is passive 3D TVs. With passive 3D, each eye reads every other line of resolution, so you're essentially watching a film at half the resolution that it is displayed in. On a Full HDTV screen, users are perceiving images at a 540p resolution, which is lower than high definition. With a 4K resolution, users perceive the images at 1080p or full high definition.

New technology is being implemented to perfect 4K Ultra HDTV, which has the potential to display TV and film with more clarity, finer detail and greater texture, making the images smoother and life-like. There are many benefits of 4K TV that should make buyers rethink their next TV purchase:

1. 4K/UHD technology results in smaller pixels compared to HD screens of the same size, which means you'll see a more detailed picture when sitting up close.

2. A large screen 4K panel delivers a smoother looking image than an equivalent Full HD screen because the pixel density is four times greater.

3. All 4K TVs upscale regular 1080p HD content for an Ultra HD viewing experience. So all Full HD video sources should look better on a 4K screen.

4. 4K Ultra HD supports faster frame rates, insane contrast dynamics and extended colors.

5. A 4K TV with Ultra High Definition JPEG playback will reveal four times the picture information.

Pricing for 4K UHDTV will vary by brand and has not yet been released for all models. They are estimated to be in the $20,000 price range for 84” models from brands like LG and Samsung. Westinghouse will sell budget 4K UHDTV, starting at 2,499 $ for a 50” set, 3,000 $ for a 55” set, and 3,995 $ for a 65” set. These will not be Smart TVs nor will they offer 4K up-conversion processing technologies. For those features, buyers will have to use an 4K processing converter found in select Blu-ray players. High-end brands introducing ultra 4K UHDTV this year on the world market include manufacturers of Sony, Toshiba, Sharp and other.

At present, Sharp is the first manufacturer to create 70” class 4K LED TV with THX certified for audio reproduction 2D and 3D playback, which prototype is shown in **Figure 4.** Sharp’s LC-70UD1U 4K Ultra HD LED TV, much like other 4K TV on the market, includes a built-in resolution upscaler, active 3D technology with 2D to 3D conversion, built-in Wi-Fi and more. This TV set is the perfect size for someone who wants a TV bigger than 65”, but smaller than 80”, and its price is about 3,500 $.

IV. ENHANCED VISUAL DISPLAY OF 4K SATANDARD

The new 4K TV standard cannot physically show the same content as 4K movies sent to theaters is just part of the equation. After all, by the time consumers get their hands on movies for 4K televisions, what they are watching will be even more-removed from the in-theater experience thanks to video compression.

The 4K UHDTV standard includes several technical enhancements over current generation high definition TV sets.

- Higher resolution - 4x the pixels, 4K 4096x2160 resolution compared to 3840x2160 with Ultra HDTV and 1920x1080 with Full HDTV.
- Bigger color space - 64x the big color range with 10-bit color, what is 1.07 billion colors, versus Full HDTV 8-bit (16.77 million colors).
- Higher frame rate - 4K includes support for frame rates up to p120 compared with the Full HD up to p60 value.
- Wider luminance Range - Initially the brightest and darkest 4K pixels are similar to Full HD, although the luminance will probably be widened. The ITU-R is exploring the extension of the luminance range.

Most 4K Ultra-HDTV includes support for 3D space that looks better than ever. Passive 3D technology is widely used by Ultra HDTV manufacturers because each eye will see a full 1080p image. With a full 1080p picture for each eye, you experience greater detail and less eye fatigue. In addition, passive 3D glasses are lightweight and cost much less than active glasses.

The 4K Ultra HD standard offers four times the resolution of 1080p HDTV (twice as many pixels in each direction, horizontally and vertically). The decreased pixel size of 4K UHDTV dramatically improves picture clarity. Meanwhile, 4K Ultra HD's deeper, broader color palette makes everything you watch more vibrant and lifelike, giving you a phenomenal viewing experience. A common argument in favor of 4K resolution for high-definition displays is that it finally offers a way to bring home movies at the same resolution they are shown in theaters.

Furthermore, the 4K Ultra-HD TV sets are already available with Liquid Crystal Display (LCD) and Light Emitting Diodes (LED) displays. Eventually, it is possible to we'll see Organic Light Emitting Diode (OLED) displays with 4K Ultra HD capability as well.

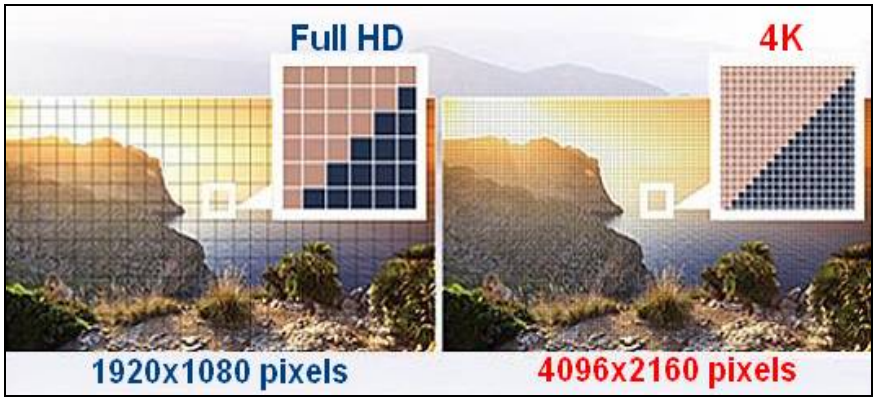

Figure 5. Resolution of TV pixel density for Full HD and 4K Standards – Courtesy of Brochure: by Paul's [2]

The OLED option will arguably provide the best possible picture. The OLED technology is lightweight, super thin and gives you crisp, vivid color from wider viewing angles than either LCD or LED displays. As stated earlier, ultra high definition is a new resolution with more than 8 million pixels. That is over six million more pixels than a Full HD TV. In fact, people will one day look back on regular HDTV and wonder how they ever watched such a low-resolution image.

On the other hand, the Full HDTV has more than six times as many pixels as a High DTV, and the image on the HDTV seems fuzzy and pixilated in comparison. Well, the ultra high definition 4K resolution has four times as many pixels as a Full TDTV one.

An 65" Full HD 1080p LED has over 2 million pixels, which means the pixel density is about 34 ppi (pixels per inch), which sample is shown in **Figure 5 (Left).** An 65" Ultra HD 4K TV has a pixel density of about 68ppi, giving to viewer two times the amount of detail, which sample is shown in **Figure 5 (Right).** The higher pixel density means that there will be more detail and less discernible pixels on your content. Thus, all digital images, like the ones in viewer television, camera, cell phone and computer monitor, are made up of pixels, known as picture (pix) elements (el). The more pixels that can be used to represent an image, the closer that image will be to the original.

With 4K Ultra HD, the pixels are so small that viewer can still experience a seamless picture at a closer viewing distance, which distance is shown in **Figure 6 (Above)**. For example, you can sit closer to an 84" 4K Ultra-HD TV than to a 46" Full HDTV. The sample of the viewer distance from Full HDTV is illustrated in **Figure 6 (Bellow).** With double the resolution and deeper, richer colors, 4K Ultra HD gives to viewers the ultimate and smooth picture with excellent resolution [1, 2, 5, 6].

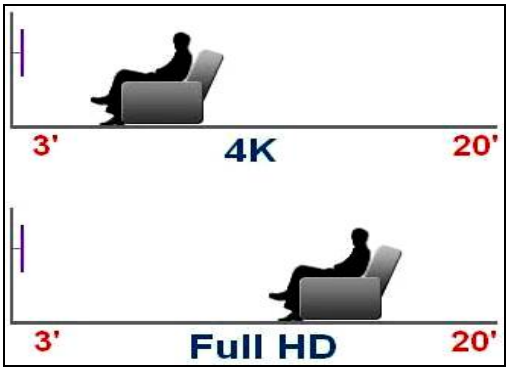

Figure 6. Viewer Distances for 4K and FHDTV – Courtesy of Brochure: by Paul's [2]

Figure7. Comparison of AVC/H.264 and HEVC/H.265 Video Compression – Courtesy of Paper: by Cox [4]

V. VIDEO COMPRESSION OF 4K STANDARD

The significant increase in the video data rate poses a key challenge to new UHDTV service offerings, since transmission bandwidth is a valued and costly resource. The resulting increase in the compressed bit rate does not scale by the same 10x factor as the uncompressed pixel rate, with the exact ratio being content and operating-point dependent. Thus, to address this challenge, the High Efficiency Video Coding (HEVC/H.265) video compression standard, ratified in January 2013, provides an 2x improvement in coding efficiency compared to the Advanced Video Codec (AVC/H.264) video compression standard and a 4x improvement compared to the Moving Picture Experts Group-2 (MPEG-2) video compression standard.

The HEVC solution is the newest video coding of the ITU-T (Telecommunications) Video Coding Experts Group and the ISO/IEC MPEG. The main goal of the HEVC standardization effort is to enable significantly improved compression performance relative to existing standards, in the range of 50% bit-rate reduction for equal perceptual video quality. The HEVC mode is designed to achieve multiple goals, including coding efficiency, ease of transport system integration and data loss resilience, as well as ease of implementation using parallel processing architectures. The HEVC standard is also known as H.265 or MPEG-H part 2 and will be the delivery path for UHDTV.

Of course, nothing is too simple, but to be clear difference in video compression in **Figure 7 (Left)** is shown image of AVC/H.264 resolution and in **Figure 7 (Left)** is illustrated image for achieved progression of new HEVC/H.265 resolution used in 4K TV technique.

The example bit rates in **Table 1** shows how compressed bit rates scale for Full HD, Ultra HD and 4K formats. Note these examples are estimates with actual bit rates in practice depending on the content and encoding complexity. However, as the table indicates, there is an approximate 150% to 250% increase in compressed bit rate for each UHDTV bitstream as compared to an HDTV bitstream, even after incorporating the 2x increased coding efficiency provided by the HEVC/H.265 video compression standard for the UHDTV formats. While there have been UHDTV demonstrations using AVC/H.264, it is

generally accepted that any realistic UHDTV service cannot use AVC/H.264 and must utilize HEVC/H.265 for the increased coding efficiency it provides [4, 6, 7].

Table 1. Comparison of TV Formats Resolution

Resolution	Codec	Bit Rate
Full HD 8 bit 1920x1080p30	AVC	6 Mb/s
Ultra HD 10 bit 3840x2160p24	HEVC	10 Mb/s
4K 10 bit 4096x2160p60	HEVC	15 Mb/s

VI. CONCLUSION

The second round of new 4K UHDTV standard in 2014 are hitting the market, and at much lower prices than they were last year. Plus, they are coming from big-name vendors like Sony, Sharp, Philips, Panasonic, HiSense and other producers. Ultimately the HEVC codec will provide up to 50% bandwidth savings for today and tomorrow's television broadcasting. After contributing significantly to the standardization effort, worldwide vendors will offer one of the most advanced implementations of the standard that broadcasters can deploy in the field to benefit from these bandwidth savings.

In addition, vendors will offer its first deliveries of HEVC on the current 4K product line supported by the MPEG-H.265 bandwidth efficient compression technology. In fact, these encoding solutions are deployed widely for broadcast contribution link digital TV distribution networks, multi-screen live streaming, Over-the-Top (OTT) platforms for PC configurations, connected TV sets, mobile devices and cellular phones including Video-on-Demand VOD applications. The 4K Proof of Concepts and trials are at an all-time high while distributors, aggregators and service providers scramble to deliver the first immersed viewing experience to the home.

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