Retrospective for Development of Ultra High Definition Television (UHDTV) Standards

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Abstract: This article describes the development retrospective of analog television (TV) and upgrading of a new digital and High Definition Television (HDTV) solutions for public and household applications. With the exception of the revolutionary move from analog to digital, television has generally evolved gradually, driven by a calculated combination of technology advances, the desire to refresh the consumer electronics market and an often industry-inflamed public demand for more and better entertainment options. Over the years, consumers have been offered "cable-ready" devices to pick up the hundreds of channels being broadcast by cable systems and a wide variety of high definition televisions with varying levels of pixel quality in both interlaced and progressive format. Most recently, leveraging existing HD standards and some theatrical successes, Consumer Electronics (CE) manufacturers, programmers and content delivery networks have endeavored to introduce 3 Dimensional TV (3DTV) into the marketplace with varying degrees of success. Here is also shortly given a look at the differences between analog, digital, HDTV and UHDTV, with current 4K and forthcoming 8K TV systems.

Keywords: HDTV, UHDTV, CRT, NTSC, DTV, SDTV, 4K UHDTV, 8K UHDTV

I. INTRODUCTION

Since its initial development in the 1920's, the first public broadcast in 1939, and widespread adoption of new technology worldwide in the 1950's, television rapidly continues to mesmerize its worldwide audience. Spanning from the time of original electro-mechanical rotating mirror-drum scanners and Cathode Ray Tubes (CRT), to today's public and household studios stapled of the flat screen television. The HDTV solution, also known as Full HD (1920×1080 px) was introduced to the USA in the 1990's, and along with the personal smart phone remains among the most popular consumer electronic devices in history.

However, television is destined to evolve once again in its developments and in such a way to bring technology revolution with last technique and innovation of Ultra HDTV design in public and household environments.

When the first HDTV sets hit the world electronic market in 1998, households, movie buffs, sports fans, public viewers and tech aficionados got pretty excited and for good reason they improved their entertainment. Ads for the sets hinted at a television paradise with superior resolution and digital surround sound. With HDTV, people could also play movies in their original wide screen format without the letterbox "black bars" that some individuals find annoying.

But for a lot of people, HDTV has not delivered a ready-made source for transcendent experiences in front of the tube. Instead, people have gone shopping for a TV and found themselves surrounded by confusing abbreviations and too many choices. Some have even hooked up their new HDTV sets only to discover that the picture doesn't look much better. Fortunately, a few basic facts easily dispel all of this confusion [1, 2, 3].

Figure 1. Analog TV Set – Courtesy of Paper: by Wilson [1]

II. ERA OF ANALOG AND DIGITAL TELEVISION SYSTEMS

The UHDTV is already in our homes together with its improved version of 4K, but new 8K TV design is coming on the scene and it is going to happen sooner than anyone first anticipated.

For years, watching TV has involved analog signals and Cathode Ray Tube (CRT) sets. The signal is made of continually varying radio waves that the TV translates into a picture and sound. Thus, an analog signal can reach a person's TV over the air, through a cable or via satellite, which sample of TV is shown in **Figure 1.** Therefore, analog TV set cannot use digital signals without an adequate set-top converter. Digital signals, like the ones from known DVD players, are converted to analog when played on traditional TVs.

This system has worked pretty well for a long time, but it has some limitations:

Conventional CRT sets display around 480 visible lines of pixels. Broadcasters have been sending signals that work well with this resolution for years, and they can't fit enough resolution to fill a huge television into the analog signal. Analog pictures are interlaced a CRT's electron gun paints only half the lines for each pass down the screen. On some TV sets, interlacing makes the picture flicker. Converting video to analog format lowers its quality.

The TV broadcasting system is currently changing to Digital Television (DTV). A digital signal transmits the information for video and sound as ones and zeros instead of as a wave. For over-the-air broadcasting, DTV will generally use the UHF portion of the radio spectrum with a 6 MHz bandwidth, just like analog TV signals do, which has several advantages:

- The picture, even when displayed on a small TV, is better quality.
- A digital signal can support a higher resolution, so the picture will still look on a larger TV screen.
- The video mode can be progressive rather than interlaced, so in such a way the screen shows the entire picture for every frame instead of every other line of pixels.
- TV stations can broadcast several signals using the same bandwidth. This is called multicasting.
- If broadcasters choose to, they obviously can include interactive content (information) with the DTV signal.
- It is also able to support high-definition (HDTV) broadcasts.

However, DTV solution also has one really big disadvantage: Analog TVs can't decode and display digital signals. When analog broadcasting ends, you'll only be able to watch TV on your trusty old set if you have cable or satellite service transmitting analog signals or if you have a set-top digital converter.

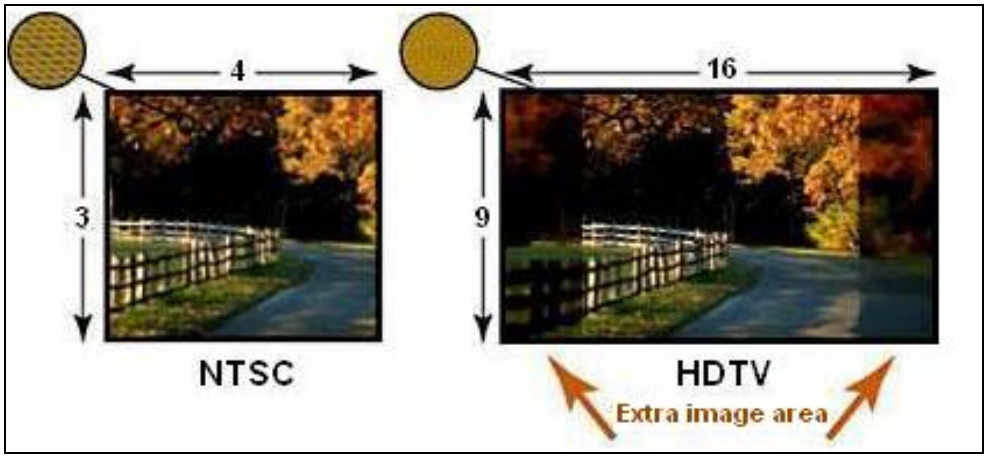

Figure 2. Standard NTSC vs. HDTV Aspect Ratio – Courtesy of Brochure:" by Wilson [4]

This innovation brings technology to the first big misconception about HDTV standard. Everything seems to be just simply, when some country is switching to HDTV, that all they'll need for HDTV is a new TV and that they'll automatically have HDTV when analog service ends. Unfortunately, none of this is true and so easy. In fact, HDTV is just one part of the DTV transition, so is necessary to realize what makes it different from DTV, in the next section.

One of analog TV standard is named after the National Television System Committee (NTSC) that was used in most of the Americas and some West Pacific countries. Most countries using the NTSC standard, as well as those using other analog television standards, have switched to newer digital television standards, there being at least four different standards in use around the world. In **Figure 2 is** shown the comparison between previous NTSC and new HDTV standard. New HDTV standard is providing two extra image areas on both sides and better resolution, which is presented in the right circle [3, 4, 5, 6].

The type of screen can be standard usually used for Standard Definition TV (SDTV) with 480p resolution, shown in **Figure 3 (Left),** and wide screen usually used for HDTV with resolution of 720p or higher, shown in **Figure 3 (Right).**

There are two methods for refreshing screens:

1. Interlacing (i) – This method means that every other line is updated with each refresh. The complete screen is updated 30 times per second because it takes 2 refreshes to completely update the screen. Since there are 60 half-screen refreshes per second, the screen is completely refreshed only 30 times per second. Interlacing reduces the amount of bandwidth required to refresh the TV image. On small TV sets, this type of refresh is hardly noticeable. As analog TV sets become larger, interlacing may produce a noticeable flicker.

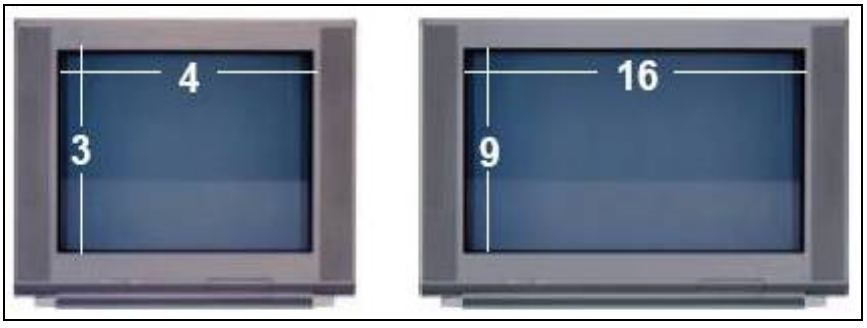

Figure 3. Standard vs. HDTV Aspect Ratio – Courtesy of Brochure:
by CharterCom [7]

2. Progressive (p) – This method means that every line on the screen is updated, in sequential order, with each refresh, so the complete screen is updated 60 times per second. Progressive refresh requires more bandwidth than interlacing, but produces a much smoother picture with almost no flicker.

Finally, North America, parts of Central America and South Korea are adopting the Advanced Television Systems Committee *(*ATSC*)* standards, while other countries have adopted other standards. These standards include how sound and video are encoded and transmitted. They also provide guidelines for different levels of quality.

All of the digital standards are better in quality than analog signals [2, 3, 7].

In the next stage of developments this standard is slowly being replaced by HDTV generation as the top tier of all the digital signals.

The ATSC has created 18 commonly used digital broadcast formats for video. Thus, the lowest quality digital format is about the same as the highest quality an analog TV can display. The 18 Primary DTV standard formats have shown in **Table 1.**

Table 1. Standard vs. High-definition Aspect Ratio

	Resolution	Aspect Ratio	Frame Rate
	(- = Interlocated, p = Progresive)		
SDTV	704x480	16:9	24p, 30p, 60i, 60p
	704x480	4:3	24p, 30p, 60i, 60p
	640x480	4:3	24p, 30p, 60i, 60p
HDTV	1920x1080	16:9	24p, 30p, 60i
	1280x720	16:9	24p, 30p, 60p

These standards cover differences in:

1. Resolution – The lowest standard resolution (SDTV) will be about the same as analog TV and will go up to 704 x 480 pixels. The highest HDTV resolution is 1920x1080 pixels. Thus, HDTV can display about ten times as many pixels as an analog TV set;

2. Aspect ratio – Standard television has an 4:3 aspect ratio and it is four units wide by three units high. In such a way HDTV has a 16:9 aspect ratio, more like a movie screen; and

3. Frame rate – A set's frame rate describes how many times it creates a complete picture on the screen every second. DTV frame rates usually end in “i” or “p” to denote whether they are interlaced or progressive. DTV frame rates range from 24p (24 frames per second, progressive) to 60p (60 frames per second, progressive).

Many of these standards have exactly the same aspect ratio and resolution, and their frame rates differentiate them from one another. When you hear someone mention a "1080i" HDTV set, they’re talking about one that has a native resolution of 1920 x 1080 pixels and can display 60 frames per second, interlaced [3, 8, 9].

III. INTRODUCTION TO THE ULTRA HIGH DRFINITION TELEVISION (UHDTV)

The HDTV standard is recently being deployed throughout the world scene and many ambitious broadcasters are devoting resources to HD TV program production and delivery. However, in the meanwhile, it might be time for R&D departments to think about the future of television system and broadcasting.

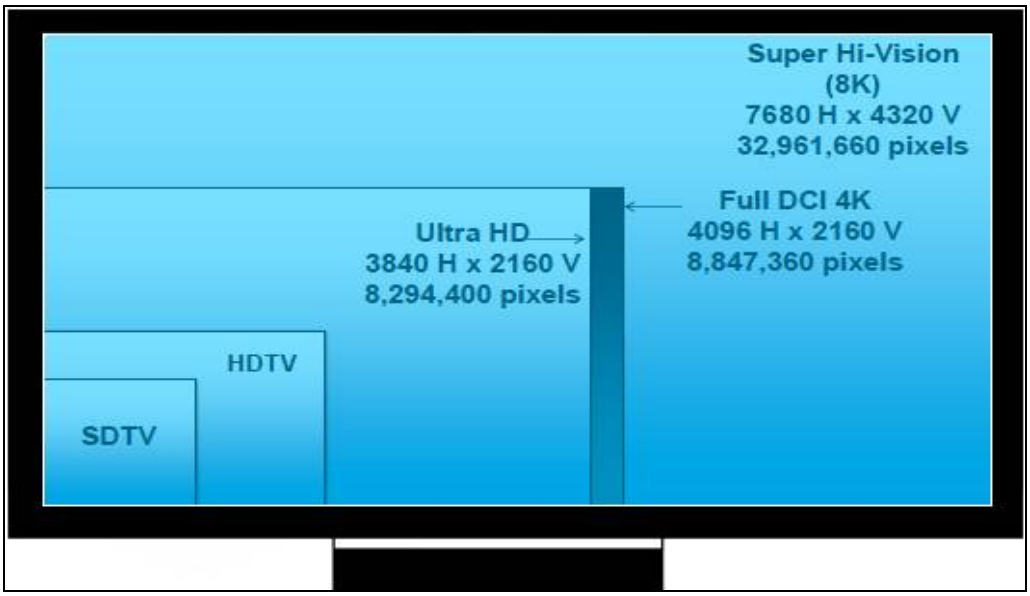

Figure 4. Comparisons of SDTV, HDTV, UHDTV, 4K and 8K Standards – Courtesy of Booklet: by SES [8]

When thinking about the future, it is always useful to look back on the past. Television history from the analog TV to the advent of SDTV standard was based mainly on increasing the number of scanning lines to achieve higher definition. In fact, some of the TV systems that were developed during this period were even called "high definition".

Efforts to enlarge the TV screen were accelerated after standardization of NTSC, PAL and SECAM systems brought the scanning-line competition to an end. Enlargement of the screen meant an enlargement of the visual field occupied by its image, that is, matching the performance of the TV to the Human Visual System (HVS). The R&D efforts on Super Hi-Vision are intended to explore the next-generation television system to succeed HDTV at some point in the future, and it consists of ultra-HD images and three-dimensional multichannel sound.

It seems that new developed HDTV is just now catching on with many homes presently owning an HDTV and more other options now available through satellite, cable, streaming, and blu-ray for watching HDTV content. There are even better standards on the horizon.

One of these has just been approved that's being called Ultra High Definition TV (UHDTV), which recently was approved by the ITU (International Telecommunications Union) in Geneva.

Thus, the first solution of UHDTV is 4K standard, which is being used in many digital movie and home theaters, and last standard of UHDTV is 8K TV technologies that have been pushed by the known Japanese broadcasting company Nippon Hoso Kyokai (NHK).

In **Figure 4** are presented differences in size and resolution between SDTV, HDTV and UHDTV standards, including 4K and 8K as UHDTV standards. Therefore, the UHDTV and its 4K and 8K solutions are providing a large increase over the current HDTV standard which has a maximum resolution of 1920x1080 for 1080p quality which is just less than the 2K standard. The conclusion is simple, that 4K and 8K standards are not the same in size and resolutions with their basic UHDTV standard.

Although HDTV was a huge breakthrough, it has been known that the human eye can see resolutions above the current HDTV standard. For example starting with the iPhone 4 and the 3rd generation iPad Apple has supported a "retina display" that is higher resolution than current HDTV and is said to be the maximum that the human eye can see [3, 5, 8].

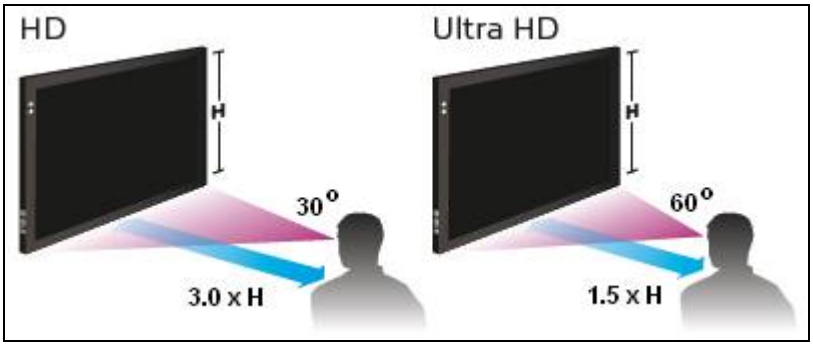

Figure 5. Comparison of Watching Distance between HDTV and UHDTV – Courtesy of Booklet: by SES [8]

There is no concern about the current HDTV equipment becoming obsolete. Because, it will be years before UHDTV content and equipment is available. It is also said that HDTV sets work well at distances up to 80 inches so in the home there would be little need for 4K sets and definitely no need for 8K sets**.**

With a field of view of 60°, a recommended viewing distances half that of HD, satellite broadcasting of UHDTV truly brings the cinema experience into the home. In **Figure 5** is shown difference of watching distances for HDTV and UHDTV, and is evident that distance for new standard is less doubled.

The ITU committee has agreed on a new draft recommendation for the UHDTV specifications. In general, today is proposed the sizes of UHDTV displays (3840x2160), and in particular is proposed the technical details for 4K (4096x2160) and 8K (7680x4320) displays. However, this proposals are subject to approval from the ITU administration, and the move would seem to confirm that both resolutions will be labeled as UHDTV, similar to how "HD" 720p sets were sold before "full HD" 1080p became the norm (standard).

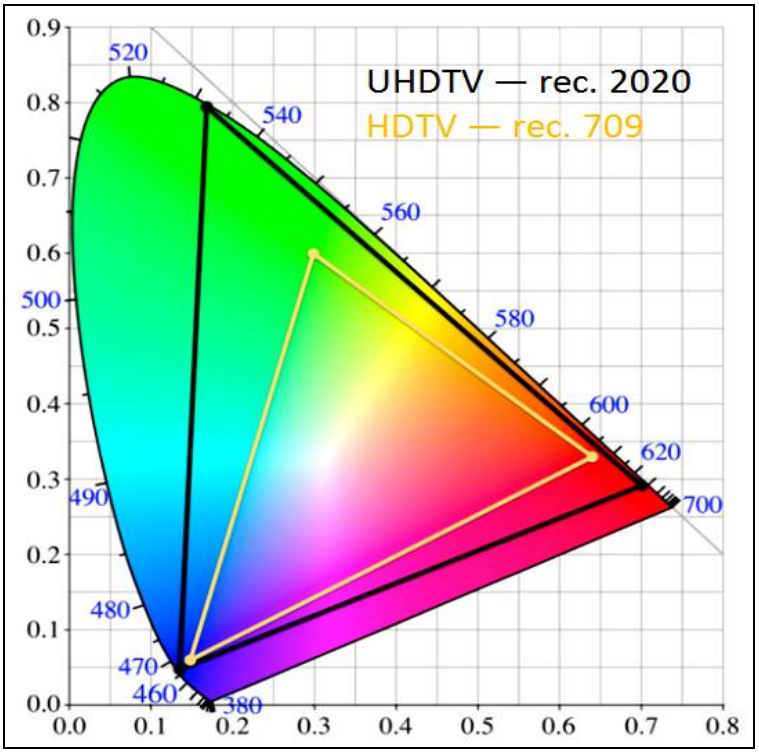

Figure 6. HDTV/UHDTV Color Gamuts – Courtesy of Paper: by Wan [2]

Figure 7. 4K UHDTV – Product of Sony Manufacturer – Courtesy of Brochure: by Sony [9]

The UHDTV standard display is an umbrella term selected by the Consumer Electronics Association (CEA) in 2012, used to describe a new high resolution video format with a minimum resolution of 3840×2160 pixels in a 16× 9 aspect ratio. In fact, the term "Ultra HD" actually refers to two different resolutions and standards: 4K UHD has 4096x2160 px and 8K UHD has 7680×4320 px.

Modern television display capabilities already exceed current color gamut standards such as ITU-R Rec. BT.709 chromaticity standard used for HDTV. Therefore, to effectively support the color reproduction capabilities of future display technologies like Organic Light Emitting Diode (OLED), an expanded color gamut is needed. ITU-R Rec. BT.2020 was announced in August 2012 to define such a color gamut.

A comparison of the BT.2020 and BT.709 color gamuts is shown in **Figure 6.** Diagram of the CIE 1931 color space that shows the Rec. 2020 (UHDTV) color space in the outer triangle and Rec. 709 (HDTV) color space in the inner triangle. Both Rec. 2020 and Rec. 709 use illuminant D65 for the white point. Both color gamuts have the same reference white but BT.2020 has a wider gamut to represent more colors, and thus requires a larger bit depth to properly sample/represent the range of colors within the gamut, which is one reason why BT.2020 is defined for higher bit depths (10-bit and 12-bit) than BT.709 (8-bit and 10-bit). The transition to 10-bit coding enables the use of a wider color gamut. Until now, this would not have been possible without most likely generating artifacts from a sparse sampling of a larger color gamut with 8-bit coding.

Before the CEA announced UHDTV as the official term to describe the new television format however, it was (and still is) known as Super Hi-Vision, which was conceptualized and developed by the Japanese public broadcasting network, NHK. By today's standards and definitions, Super Hi-Vision is equivalent to 8K Ultra HD, that is, both feature a 7680×4320 px resolution [2, 3, 6, 8].

IV. NEW IMPLEMENTED 4K ULTRA HDTV

As stated earlier, 4K Ultra HDTV (UHDTV) is one of the two Ultra HD formats. Unfortunately, a common misnomer arises when describing 4K terms has to be clear up in case of any further confusion. Technically speaking, 4K is not the same as 4K Ultra HD standard. In such a mode, the standalone term "4K" was originally used to describe digital cinema (4096×2160 px).

Figure 8. 8K UHDTV – Prototype of Sharp Manufacturer – Courtesy of Brochure: by Cohen [10]

Since digital cinema resolution is not available in a consumer home television, the term "Ultra HD" (3840×2160 px) and "4K UHDTV" (4096x2160) were invented. It has to be noticed that the slight reduction in 4K Ultra HD resolutions is to achieve a 16×9 aspect ratio.

The advantage of the 4K Ultra HD 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 Ultra HDTV 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 TV producers, like Sharp, Toshiba, TCL, and HiSense will begin offering 4K Ultra HDTV's toward the end of 2013.

The second round of 4K HDTV 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, Samsung, and LG.

In **Figure 7** is illustrated new 4 K UHDTV of Sony producers. Now that there are 4K HDTV displays in the mid-four figure range, still too dear for most of future customers, but not unlike what big-screen plasma TVs cost in, say, 2005 it is more realistic to look at them now, even if they are still too expensive for most of customers today [3, 9, 10, 11].

VII. NEWCOMER 8K ULTRA HDTV

The last developed 8K Ultra HDTV is the second of the two Ultra HDTV formats, featuring a 7680×4320 px resolution, which is exactly 16 times the resolution of Full HD or 4K UHDTV. The design of 8K UHDTV prototype of Sharp producer is illustrated in **Figure 8**.

The new television standard is the largest UHDTV resolution to exist in digital television and digital cinematography. It refers to the horizontal resolution of these formats, which are all on the order of 8,000 pixels, forming the total image dimensions (7680x4320). In such a way, this standard provides a display resolution that may eventually be the successor to current 4K resolutions.

Today, the 4K standard is speculated to become a mainstream standard in televisions by 2017. One advantage of high-resolution displays such as 8K is to have each pixel be indistinguishable from another to the human eye, at a certain distance away. On an 8K screen sized 52", this effect would be achieved in a distance of 20" from the screen, and on a 92" screen at 3' away.

Another practical purpose of this resolution is in combination with a cropping technique used in film editing. This allows filmmakers to film in a high resolution such as 8K, with a wide lens, or at a farther distance from a potentially dangerous subject, intending to zoom and crop digitally in post-production, a portion of the original image to match a smaller resolution such as the current industry standard for High-definition televisions (1080p, 720p and 480p).

Few film cameras have the capability to film in 8K, with innovators NHK being one of the only companies to have created a small broadcasting camera with an 8K Image sensor. Sony and Red Digital Cinema Camera Company are both working to bring larger 8K sensors in more of their cameras in the coming years.

Although 8K will not be a mainstream resolution anytime soon, a major reason filmmakers are pushing for 8K cameras is to get better 4K footage. Through a process called down sampling, however, using a larger 8K image down sampled to 4K could create a sharper picture with richer colors than a 4K camera would be able to achieve on its own with a smaller sensor.

Therefore, the 8K Ultra HD technology is still largely experimental at this point, with only one 8K Ultra HDTV being featured at CES 2013 by Sharp.

Having seen this resolution in person, it is possible to conclude that the astounding video quality cannot be described with words, nor can a still photograph accurately represent the sheer awesomeness of this video resolution. When 8K Ultra HD is combined with 22.2 surround sound, NHK advocates this as Super Hi-Vision**.**

Otherwise, 8K Ultra HD is still at least several years away from living room of future consumers. Three main obstacles must be overcome to bring this resolution to mainstream: Storage, Bandwidth, and Content.

In the meantime, similar to the previous standards, various 8K Ultra HD products are being designed, such as the AH-4800 camera by Astro Design, capable of recording 8K resolution and other relaying products [1, 3, 10, 13].

6. Conclusion

The HD technology is very slow steps closer to the homes of ordinary users and it will take a lot of time to get this standard in reality. In addition, the quantity of high resolution is not available in large numbers and at reasonable prices.

Only when movies on HD DVD and new Blu-Ray media arrive in large quantities and at affordable prices, and when the supply of terrestrial TV companies and satellite providers become richer by the number of channels, only then will the investment in this technology will pay off. It is estimated that more than 25 million households in the United States has a HD Ready TV.

However, only half of this number can truly enjoy the HD signal. Thus, the situation is constantly improving due to the increasing offer HD TV receiver, satellite receiver, and the amount of HD material is also on the rise.

Today most people sentenced to watching DVD sets and just the odd HD channels on satellite, and that certainly is not a sufficient reason for the investment of tens of thousands of domestic or foreign currency. When technology improves and prices fall, and certainly users will in the future see a lot of quality video material.

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