Super Hi-Vision

— research on a future ultra-HDTV system

Masayuki Sugawara
NHK

This article briefly describes the current status of R&D on the "Super Hi-Vision" television system in Japan. 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. The conceptual ideas behind the research project and the status of the technological developments are described. The collaboration between various EBU Members and NHK is also mentioned.

HDTV is now being deployed throughout the world and many broadcasters are devoting resources to HD programme production and delivery. In the meanwhile, it might be time for R&D departments to think about the future of television and broadcasting. When thinking about the future, it is always useful to look back on the past. Television history from the time of Baird and Takayanagi to the advent of SDTV 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 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).

Fig. 1 illustrates the changes in TV screen sizes in Japan since the 1950s. TV screens have consistently become larger, from 12 inches in the 1950s to the current 50 inches. Two difficulties arose as TV screen sizes grew. One is the picture quality degradation caused by the shortening of the relative viewing distance – since the absolute viewing distance at home does not change much. The other is how to make such a large screen. HDTV was the solution to the first problem, and flat-panel displays were the solution to the second one.

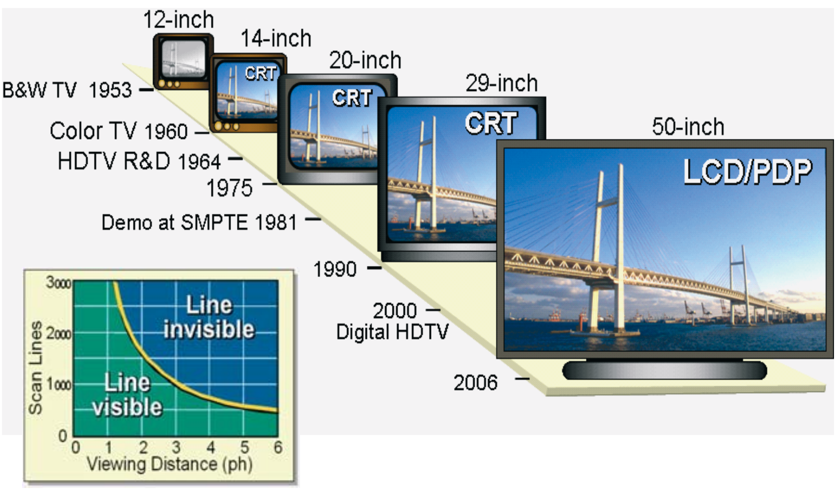

Figure 1
HDTV plays a key role in introducing a large screen into the home.

Beyond HDTV: why 8k x 4k?

HDTV was to be an almost "transparent" medium when viewed at a distance of three picture heights [1]. Its recent popularity seems to attest to this. Nevertheless, we know that HDTV is not genuinely transparent nor the final development. David Wood, Head of New Technology at the EBU, mentioned in the July 2007 issue of EBU Technical Review [2] that public expectations for quality rise over time, and are part of the process of human self-education. The more we see higher quality, the more we become accustomed to it, and the less we accept lower quality. It is human nature to seek better visual experiences, and today's HDTV might be considered just a step in the journey to match the range of the human visual system. To reach the end of this journey, quite a few parameters need to be investigated.

Among the parameters we consider most important is coverage of the visual field. To what extent should the visual field be covered by the screen? 360º surround screens and head-mounted displays with motion tracking are under study in the field of virtual reality. However, ours is a television application, and our target coverage should reflect that. Similar to the situation of viewing current TV screens, the screen would thus be rather flat, displaying a 2D image, and it would be viewed by individuals or groups.

The psychological effect of widening the visual angle usually appears as an increase in the sensation of presence or immersion in the image. These effects have been studied when designing new TV systems; in fact, they were studied in the early stages of HDTV development (e.g. [3][4]). Researchers at NHK recognized the importance of preceding studies and incorporated their findings into their plans for Super Hi-Vision. In addition, they conducted a new series of subjective and objective (physiological) experiments using Super Hi-Vision prototype equipment. These experiments assessed the relationship between the visual angle and the sensation of presence. The results indicate that the sensation of presence tends to level off at a visual angle of around 80 - 100 arc-degrees [5][6]. We consider this to be the maximum visual angle that Super Hi-Vision should provide to viewers.

The required angular resolution is needed to determine the pixel count of the image format, once the required visual angle is specified. Similar to the case of the visual angle, NHK researchers learned from the past literature (e.g. [7]) and conducted another series of experiments. These experiments used the discrimination threshold of resolution and the sense of realness as indices to determine the required angular resolution. The results were not far from what is generally believed to be necessary, i.e. 1 pixel per 1 arc-minute, or 30 cycles per degree (cpd), but a moderately higher resolution of 40~50 cpd is desirable for our criteria [8].

The primary difference between Super Hi-Vision and previous TV formats is the pixel count. However, other parameters are also important because they are influenced by the change in pixel count and/or visual angle. Also, even if they are not directly affected by the change in pixel count, these parameters need to be set to produce image quality and performance suitable for the increased pixel count of Super Hi-Vision. The frame frequency needs to be reviewed in light of both of those reasons. And while the increase in pixel count does not affect the colour space and transfer

Abbreviations

ARIB Association of Radio Industries and Businesses (Japan)

CMOS Complementary Metal-Oxide Semiconductor

DVA Dynamic Visual Acuity

HVS Human Visual System

ITU International Telecommunication Union
http://www.itu.int

ITU-R ITU - Radiocommunication Sector
http://www.itu.int/publications/sector.aspx?lang=en&sector=1

LSDI Large Screen Digital Imagery

NTSC National Television System Committee (USA)

PAL Phase Alternation Line

QPSK Quadrature (Quaternary) Phase-Shift Keying

SECAM *Séquentiel couleur à mémoire*

SMPTE Society of Motion Picture and Television Engineers (USA)
http://www.smpte.org/

TWTA Travelling-Wave-Tube Amplifier

function directly, it is advisable to give sufficient consideration to the view-point of pursuing higher image quality and the fact that display device technology is changing rapidly.

The current version of the Super Hi-Vision prototype is based on the conventional parameter values described in the table below but, for practical reasons, several research efforts have already started at the NHK laboratory. Of these, a recent result of a study on the relationship between dynamic visual acuity (DVA) and visual angle shows that DVA tends to increase as displays become wider in terms of visual angle [9]. This may be taken into account to determine the required frame frequency. Similarly, a review of every picture parameter would be helpful to assure a new television system will have the appropriate characteristics. The pursuit of these research activities is very desirable.

Table 1
Picture characteristics of the prototype Super Hi-Vision system

Picture aspect ratio	16:9
Horizontal pixels	7680
Vertical pixels	4320
Frame frequency	60
Image structure	Progressive
Bit/pixel	10
Colorimetry	Rec. 709

Beyond 5.1 surround sound: why 22.2?

Sound is a vital component of television systems. Since Super Hi-Vision is designed to deliver enhanced "presence", it should incorporate an audio format that matches its visual impact. Particularly, the ability to localize sound content over the widened screen images should be improved so that the horizontal and vertical image and sound match. Conventional multichannel audio systems such as the 5.1 surround sound system prioritize frontal sound reproduction at the expense of rear sound reproduction. In the case of Super Hi-Vision, it aims to provide an immersive sensation; the sound system therefore has to provide a sound field that surrounds viewers with various sound sources. Based on these requirements, the sound system on a Super Hi-Vision should:

- localize frontal sounds stably over the entire screen area;
- reproduce sound images in all directions around a viewer including elevation;
- reproduce a three-dimensional spatial impression

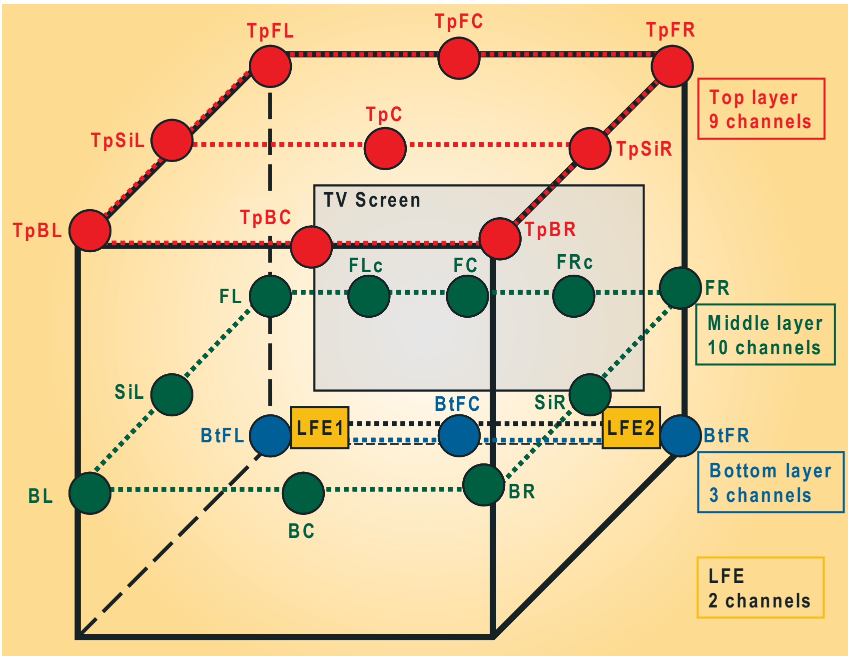

Figure 2
22.2 multichannel sound system

that augments the sense of reality;

- create a wide listening area with exceptional sound quality;
- be compatible with existing multichannel sound systems.

The 22.2 multichannel sound system was developed to fulfil these conditions. As shown in *Fig. 2*, the system consists of loudspeakers with a top layer of nine channels, a middle layer of ten channels, and a bottom layer of three regular channels and two low frequency effects (LFE) channels.

Subjective evaluations were conducted to assess the effectiveness of listening areas of three different multichannel audio systems: 2-channel stereo, 5.1 surround sound, and 22.2 multichannel sound. The results indicate that three-dimensional sound by a 22.2 multichannel sound system can produce better sensations of spatial sound quality, reality and presence in a wider listening area than 5.1 and 2.0 multichannel sound systems [10].

Status of R&D

Fig. 3 shows the Super Hi-Vision devices developed so far and the system configuration.

The first demonstration was in 2002, and it featured a prototype consisting of a camera, projection display, and frame grabber. A newer prototype was exhibited for six months at World Expo 2005 in Aichi, Japan, where it showed special Super Hi-Vision programmes to approximately 1.56 million people. The prototype system was also installed at a museum. Since 2006, it has been demonstrated in the USA (NAB 2006 and 2007) and in Europe (IBC 2006). During this time, work has continued on various elemental technologies, such as optical transmission of uncompressed video and MPEG-2 compression devices. Experiments have been conducted on indoor transmission in

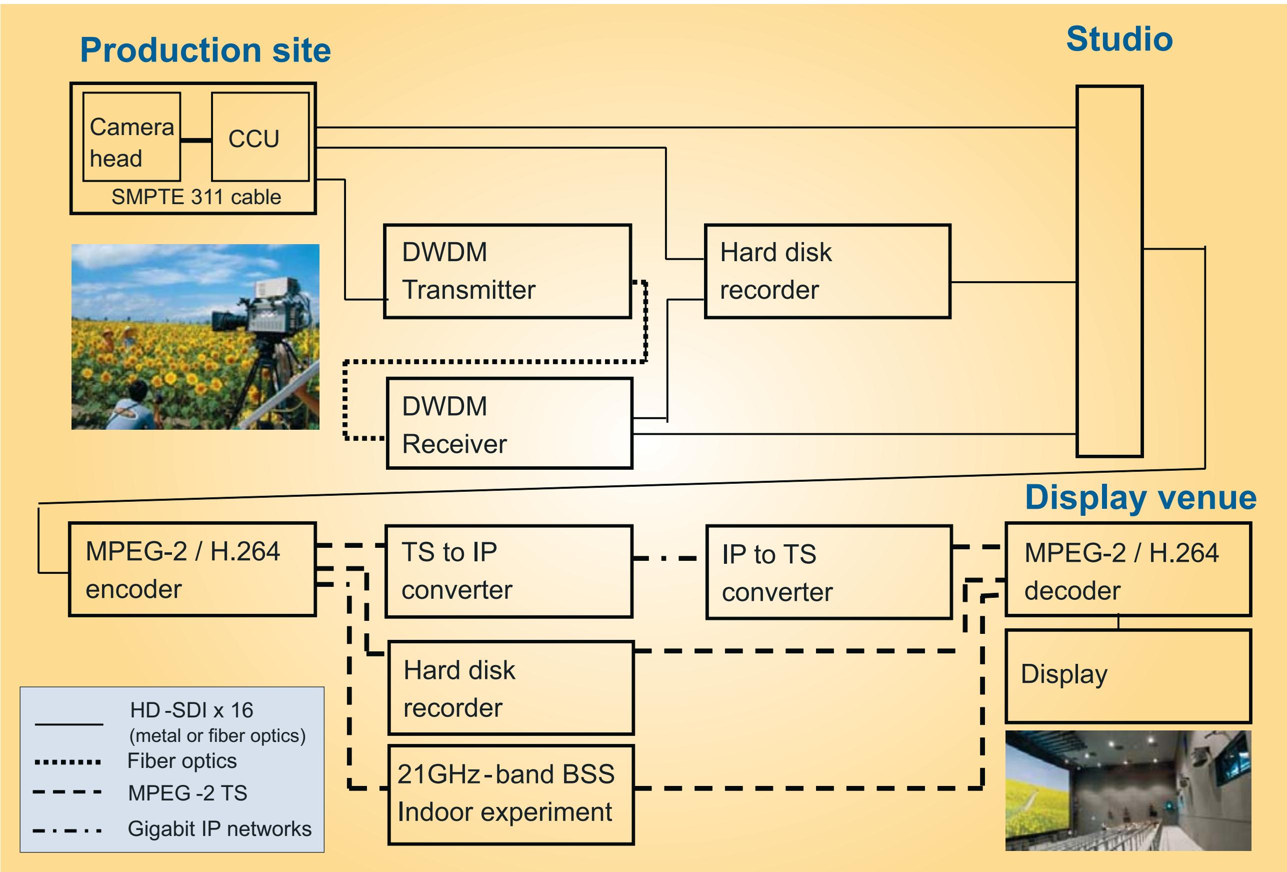

Figure 3
Current system configuration of Super Hi-Vision

the 21 GHz band and on real-time transmission of live TV programmes using the IP transport protocol.

Currently, research at NHK concentrates on developing image and display devices with the “full” resolution, i.e. 33 million pixels. Such technologies were not available at the beginning of this project; the total resolution of the prototypes had to be enhanced by pixel-offset imaging.

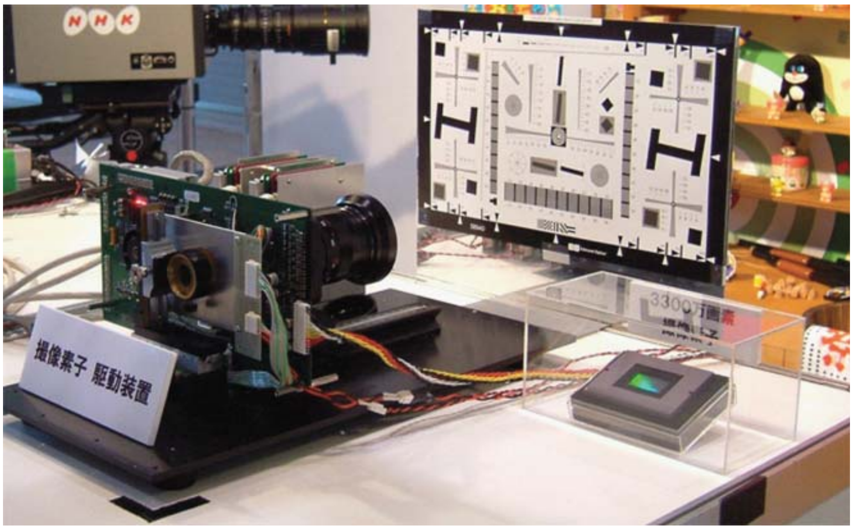

Figure 4
33 megapixel image sensor for Super Hi-Vision demonstrated at NHK Science and Technical Laboratories open house in May 2007

A full-resolution image sensor was demonstrated in May 2007 at the annual open house of the NHK Science and Technical Research Laboratories *(Fig. 4)*. The newly-developed CMOS image sensor has the pixel count of 7680 x 4320 pixels with 60 frames per second output. The advent of a “full-resolution” camera and display will enable the true picture quality of Super Hi-Vision to be demonstrated.

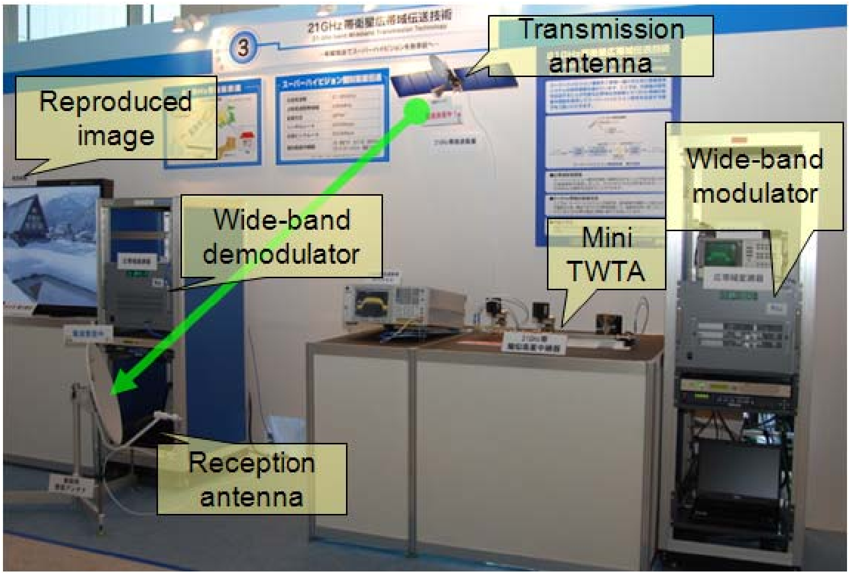

Figure 5
21-GHz-band indoor transmission experiment at open house in May 2007

The means to deliver programmes to the home and display them are big issues. Besides a broadband communications network, a broadcasting satellite system operating in the 21 GHz band is a promising candidate for the transmission path to the home. The bandwidth of the channel assigned to the 21 GHz band is 600 MHz and therefore it has the potential to handle extremely high bitrate signals. An indoor transmission experiment was demonstrated at the NHK open house in 2007 *(Fig. 5)*.

In this demonstration, a Super Hi-Vision signal compressed by MPEG-2 at 250 Mbit/s was input to a wideband modulator (300 MHz bandwidth) that can transmit a 500 Mbit/s signal by using QPSK modulation. The mini travelling wave tube amplifier (TWTA) performed wideband amplification of the signal before it was sent to the receiver on the floor via the dummy satellite antenna on the wall. The transmission length of this experiment was only two meters but it did show the feasibility of transmitting a Super Hi-Vision signal from a satellite located 36,000 km away from the earth to the home.

Needless to say, standardization of television technologies is very important. Regarding image formats, the three standards listed below deal with the image format of Super Hi-Vision.

- ITU-R Recommendation BT.1201 (1995-2004): **Extremely high resolution imagery**

Masayuki Sugawara received B.Sc. and M.Sc. degrees in electric communication engineering, and a Ph.D. degree in electronic engineering from Tohoku University, Sendai, Japan. He joined NHK (Japan Broadcasting Corporation), Tokyo, in 1983. Since 1987, he has been researching solid-state image sensors and HDTV cameras at NHK's Science and Technical Research Laboratories (STRL).

Dr Sugawara was an associate professor at the University of Electro-Communications in Tokyo from 2000 until 2004. At present, he is a senior research engineer at NHK STRL and is engaged in the research of ultra-high-definition TV systems. He is a member of SMPTE, IEEE, IEICE and ITE.

- ITU-R Recommendation BT.1769 (2006): **Parameter values for an expanded hierarchy of LSDI image formats for production and international programme exchange**
- SMPTE 2036 (2007): **Ultra high definition television – Image parameter values for program production**

In addition to these standards, standardization activities are ongoing in several bodies, including the ITU, SMPTE, and ARIB.

EBU and NHK collaboration on the future of television

Looking back at the history of HDTV, we can see that it takes tremendous effort to develop a new medium and deploy it. The same can be said of Super Hi-Vision or any kind of new media that goes beyond HDTV, even though the speed of technology advancement is accelerating. It would be impossible for any organization to finish such a difficult project on its own. Inter/intra industry collaboration would be desirable because of the public characteristics of broadcasting and programme exchanges. In this respect, collaboration between broadcasters is of the highest priority.

The BBC, RAI, IRT (all EBU Members) and NHK agreed to collaborate on broadcast technology R&D in February 2007. Moreover, in February 2008, they agreed to conduct joint research on the items listed below.

- High-efficiency image coding technology for Super Hi-Vision and virtual studio technology (BBC and NHK);
- broadcasting satellite transmission technology in the 21 GHz band (RAI and NHK).

Along with these joint research projects, the collaborators carry out discussions and information exchanges on several topics, including technologies for assisting disabled viewers.

Broadcasters are now facing harder competition than ever for the attention of viewers at home. Therefore, it is a wise move to tackle the technological developments in a cooperative way. We, at NHK, believe that this collaborative effort will bear much fruit.

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