



Super Hi-Vision

— the star of the show!

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On 12 September 2008, at 10 o'clock in the morning, more than 100 members of the press packed into the 50-seat NHK Theatre at IBC Amsterdam to witness the world's first international transmission of Super Hi-Vision programming. In the sweltering room, the potential and feasibility of Super Hi-Vision were demonstrated by the images displayed on the 275-inch screen, which were transmitted live from London City Hall and also as pre-recorded programming from Turin.

An experiment – born of meticulous planning and cooperation by eight organizations over the course of a year – was very successful and it was the most eye-catching demonstration at IBC-2008.

This article describes the collaboration between members of the Broadcast Technology Futures (BTF) group that made these demos possible.

The Super Hi-Vision (SHV) system is being developed by the NHK Science & Technical Research Laboratories (NHK STRL) as a future broadcast system that will give viewers a much greater sensation of reality. The video system has 7680 × 4320 pixels and delivers images so real that viewers almost feel they are present at the scene of the broadcast; they may even find themselves trying to touch what's on the screen. The 22.2 multichannel sound system consists of three vertical layers of loudspeakers. It produces three-dimensional spatial sound that augments the sense of reality and presence.

The first appearance of Super Hi-Vision in Europe was at IBC-2006. That demonstration was carried out by NHK and various Japanese companies but it triggered an international collaboration on broadcast technology. In 2007, four broadcast media laboratories from Europe and Japan (NHK STRL, BBC R&I, the IRT and RAI CRIT) formed a group named the **Broadcast Technology Futures** (BTF) group to work on new technologies for tomorrow's media.

The group – which is assisted by the Technical Department of the EBU – exchanges information to help define the future of media technologies. Their current projects include collaborations on meeting technological challenges related to current media and on media beyond HDTV.

A major collaborative demonstration was arranged for September 2008 at IBC – by NHK, the BBC and RAI, supported by the EBU, Eutelsat, Siemens, Cable & Wireless and SIS – to highlight the international transmissions of Super Hi-Vision programming. This collaborative exhibition proposal was made a year in advance and came true after many preliminary experiments, plans and studies had been conducted.

Overview of the Super Hi-Vision System

History

In late 1990, NHK's research scientists asked themselves, "What's next, after HDTV?" That was the starting point of our research on Super Hi-Vision. Just like in the 1960s, when STRL scientists began thinking about HDTV, our engineers started to dream of a future television system.

Some engineers began work on a 3D television system based on the principle of integral photography. Such a system does not require special glasses; when you move your head, parts of the background hidden by objects in the foreground appear. Our research on integral TV has so far produced a system with QQVGA (Quarter Quarter VGA) quality. To improve the picture quality, we need to create capture and display devices with many more pixels.



Figure 1
A futuristic living room

Other engineers began work on the Super Hi-Vision system for the living room arrangement shown in *Fig. 1*. To make this system a reality, we have to develop capture and display devices that have 33 million pixels.

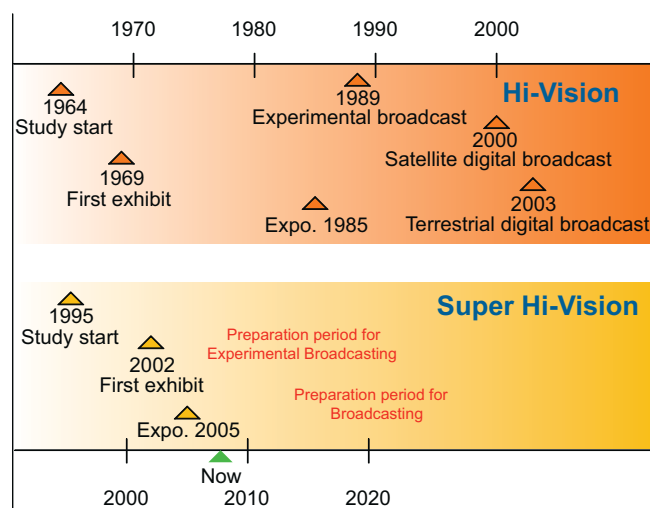


Figure 2
Roadmap

Both teams understood that the 3D television and Super Hi-Vision systems share a common technological ground. NHK began its basic research on post-HDTV in 1995, and formally decided to develop the Super Hi-Vision system with 33 million pixels and its associated equipment in 2000.

The first demonstration of Super Hi-Vision took place at the STRL Open House in 2002. We then took the system to the NAB show in Las Vegas and IBC in Amsterdam in 2006. We also gave a demonstration at Broadcast Asia in Singapore in June 2008.

Fig. 2 shows a roadmap of Super Hi-Vision research and development in comparison with that of Hi-Vision.

Video system of Super Hi-Vision

The video format of the Super Hi-Vision system is shown in *Table 1*. The number of pixels is 7680 horizontally and 4320 vertically, for approximately 33 million pixels per frame. That is four times as many pixels in the vertical and horizontal directions as for HDTV, meaning that Super Hi-Vision overall has 16 times as many pixels as HDTV.

Table 1
Comparison of video formats of HDTV and Super Hi-Vision

	Number of pixels (H x V)	Aspect ratio	Field / Frame frequency	Interlace ratio
Super Hi-vision	7680 x 4320	16:9	60.00 Hz 59.94 Hz	1:1
HDTV	1920 x 1080	16:9	60.00 Hz 59.94 Hz	1:1 2:1

The frame frequency is 60 Hz progressive, so the total information density of the Super Hi-Vision image is 32 times that of HDTV, i.e. 16 times spatially and two times temporally.

International standardization of the Super Hi-Vision format is currently underway. ITU-R has been studying large-screen digital imagery (LSDI) and extremely high-resolution imagery (EHRI), and has produced Recommendations for those image systems. The image format of Super Hi-Vision is in accordance with those standards. In particular, Recommendation ITU-R BT.1769 is based on the R&D results of Super Hi-Vision.

Table 2 shows the relationship between Super Hi-Vision, LSDI and EHRI.

Table 2
Image formats in ITU recommendations

Image format	TV Recommendation	EHRI hierarchy	LSDI Recommendation
1920 x 1080	Rec. ITU-R BT.709 (HDTV)	EHRI-0	Rec. ITU-R BT.1680
3840 x 2160		EHRI-1	Rec. ITU-R BT.1769
5760 x 3240		EHRI-2	
7680 x 4320	[Super Hi-Vision]	EHRI-3	Rec. ITU-R BT.1769

The standardization process with our North American colleagues at SMPTE began in June 2007. They quickly produced SMPTE standard 2036 in 2007, which describes the image formats for an Ultra High-Definition TV system. It harmonizes well with the ITU-R recommendations.

Sound system of SHV

The audio format of the Super Hi-Vision system is 22.2 multichannel sound, as shown in Fig 3 and Table. 3. The 22.2 multichannel sound system has three loudspeaker layers (top layer, middle layer and bottom layer), and it consists of 22 full-bandwidth channels and 2 LFE (low frequency

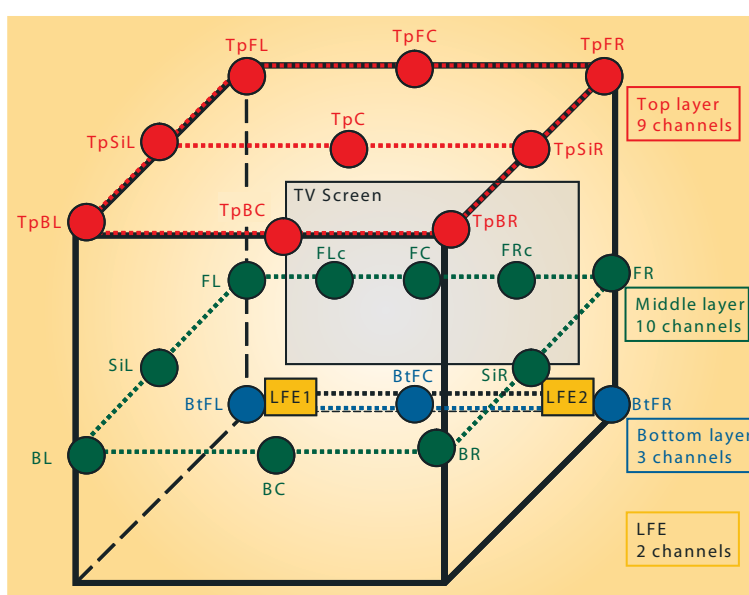


Figure 3
Loudspeaker layout of 22.2 multichannel sound system

effects) channels. It is a three-dimensional sound system, whereas the 5.1 multichannel sound system specified in ITU-R BS.775-2 is a two-dimensional sound system without a vertical dimension.

Table 3
Channel maps and labels of 22.2 multichannel sound

AES Pair No. / Ch No.	Channel No.	Label	Name
1/1	1	FL	Front left
1/2	2	FR	Front right
2/1	3	FC	Front centre
2/2	4	LFE1	LFE-1
3/1	5	BL	Back left
3/2	6	BR	Back right
4/1	7	FLc	Front left centre
4/2	8	FRc	Front right centre
5/1	9	BC	Back centre
5/2	10	LFE2	LFE-2
6/1	11	SiL	Side left
6/2	12	SiR	Side right
7/1	13	TpFL	Top front left
7/2	14	TpFR	Top front right
8/1	15	TpFC	Top front centre
8/2	16	TpC	Top centre
9/1	17	TpBL	Top back left
9/2	18	TpBR	Top back right
10/1	19	TpSiL	Top side left
10/2	20	TpSiR	Top side right
11/1	21	TpBC	Top back centre
11/2	22	BtFC	Bottom front centre
12/1	23	BtFL	Bottom front left
12/2	24	BtFR	Bottom front right

The audio sampling frequency is 48 kHz, and 96 kHz can be optionally applied. The bit depth is 16 bits, 20 bits or 24 bits per audio sample.

International standardization of the 22.2 multichannel sound system is currently underway.

ITU-R is studying the system parameters for digital multichannel sound systems. The standardization process also started at SMPTE in December 2007. In fact, SMPTE has already produced SMPTE standard 2036-2, which describes the audio characteristics and audio channel mapping of 22.2 multichannel sound for production of ultrahigh-definition television programmes. A project at IEC/TC100 is also underway to establish a new standard for the general channel assignment of multichannel sound, including the channel mapping for 22.2 multichannel sound.

Planning and cooperation for IBC 2008

Demonstration systems

The Super Hi-Vision technologies demonstrated at IBC-2008 by the international collaboration group included baseband audio-visual systems, live international transmission over an ultra-broadband IP network and via satellite, and a wavelet-based video compression system. Fig. 4 depicts the configuration of the system that was demonstrated.

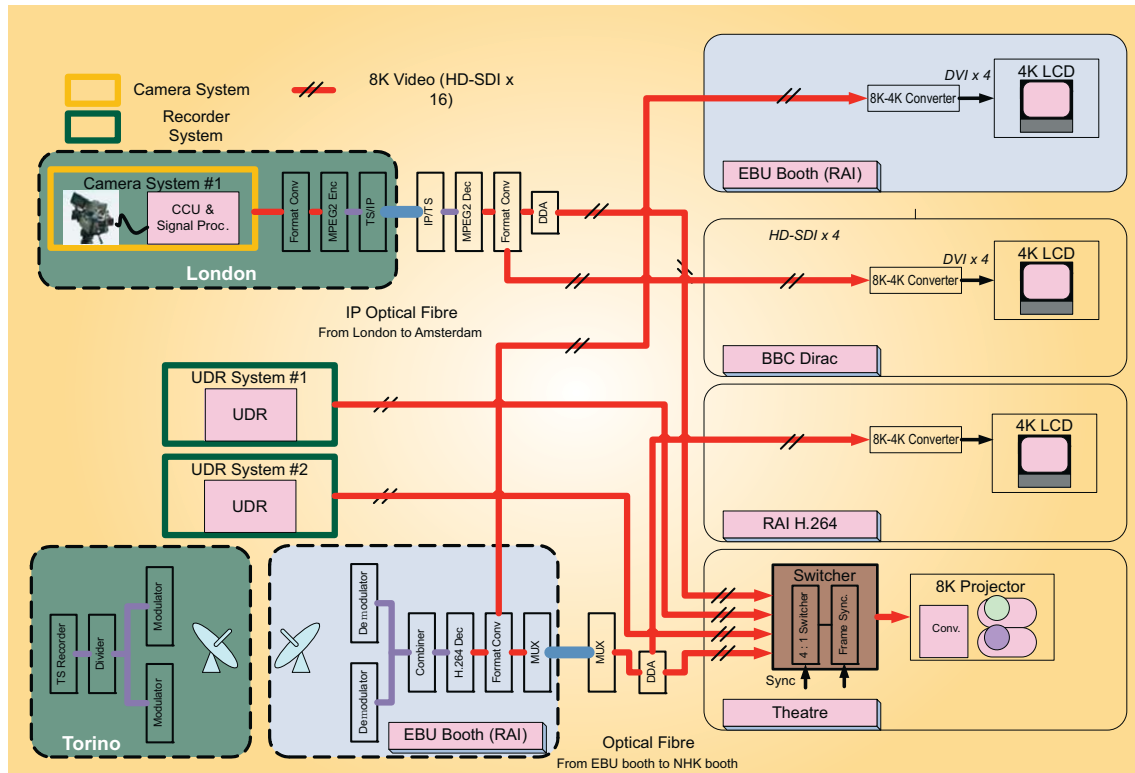


Figure 4
Configuration of the demo system

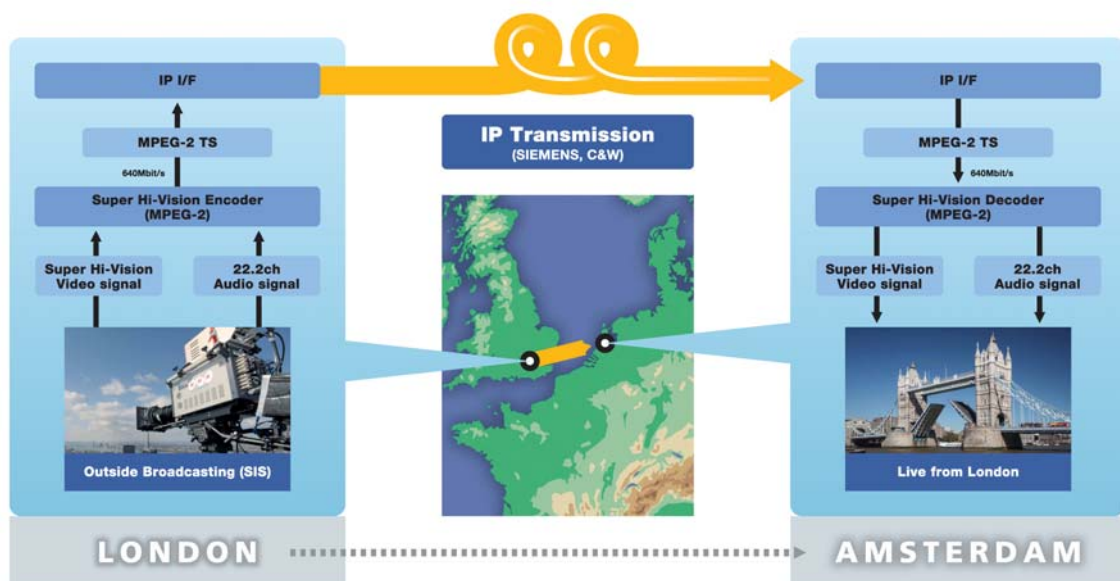


Figure 5
IP transmission of Super Hi-Vision

IP Transmission of Super Hi-Vision (Fig. 5)

The live Super Hi-Vision pictures and sound, captured by the SIS crew in central London, were sent to Amsterdam over an ultra-broadband IP network provided by Siemens and C&W. Ultra-broadband networks are becoming more widely available, so this demonstration showed the possibility of live Super Hi-Vision content being relayed from virtually anywhere in the future.

The 24 Gbit/s SHV signal was compressed to approximately 600 Mbit/s by using MPEG-2. The compressed video and uncompressed 22.2 multichannel audio were multiplexed on an MPEG-2 TS.

Satellite transmission of Super Hi-Vision (Fig. 6)

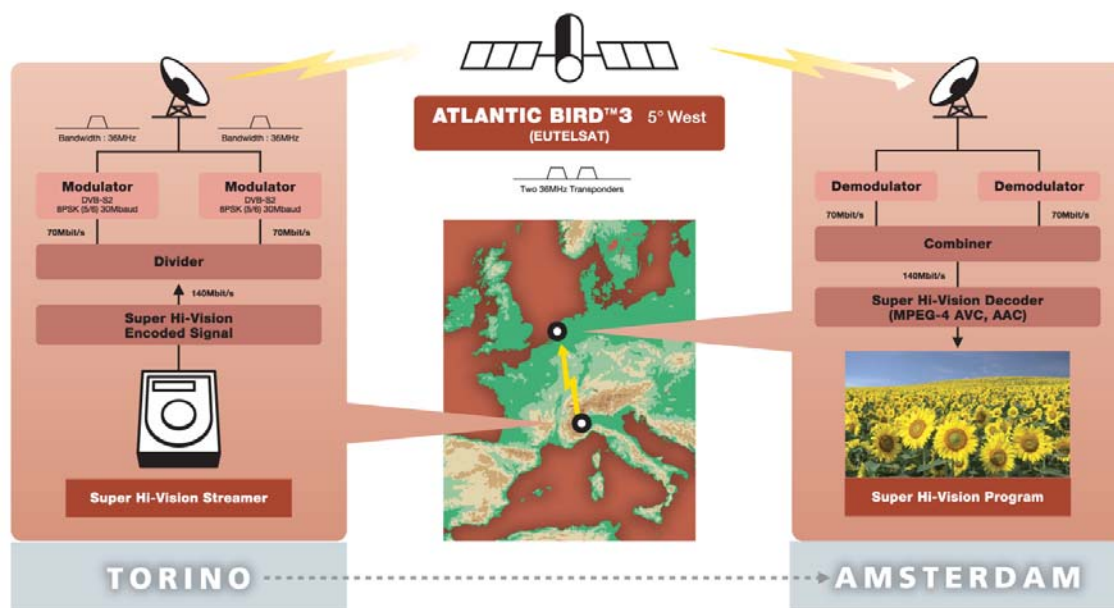


Figure 6
Satellite transmission of Super Hi-Vision

RAI and Eutelsat provided Super Hi-Vision material live via satellite from Turin, using DVB-S2 modulation with a channel efficiency that closely approaches the theoretical limit. The Super Hi-Vision video and the 22.2 multichannel sound were coded using MPEG-4 AVC and AAC, respectively. The 140 Mbit/s coded signal was divided into two transport streams (TS) and carried over two satellite transponders, using 8PSK 5/6 modulation. In the future, a Super Hi-Vision signal may be delivered to the home by Ku or Ka band satellites, using a single high-power 36 - 72 MHz transponder and high-order modulation schemes.

Video Compression: "Dirac" for Super Hi-Vision (Fig. 7)

Dirac is a video compression system devised by the BBC. NHK and the BBC are working together to develop Dirac compression for Super Hi-Vision. Dirac is based on wavelets – a different technology from MPEG. It does not break a picture up into blocks or compress each block in turn. Instead, pictures are delivered by means of a series of approximations of increasing resolution. This means that

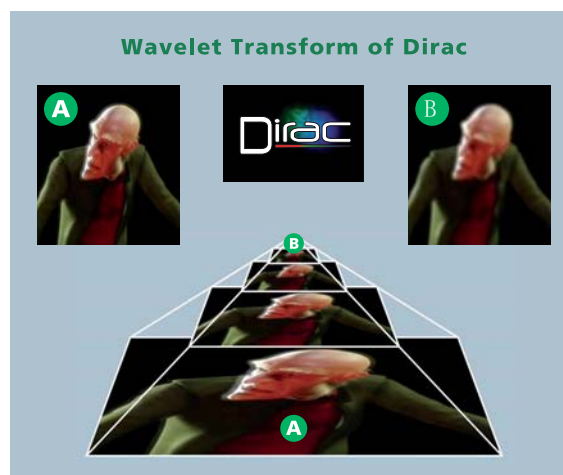


Figure 7
Dirac

Dirac can compress very high resolution images like Super Hi-Vision extremely efficiently, with detail sent only when it is needed.

Collaboration

Transmission

NHK, the BBC, Siemens and C&W cooperated on the IP transmission of the Super Hi-Vision data. The satellite transmission was handled by NHK, RAI and Eutelsat.

Between late 2007 and early 2008, the transmission paths that could be used were investigated. Then, the experiments listed below were conducted prior to the transmission experiment at IBC-2008.

Table 3
Preliminary experiments

Month (in 2008)	Organization	Item
February	RAI, Eutelsat	Measurement of transmission characteristics using the Eutelsat satellite
April	NHK, the BBC, Siemens, C&W	Testing of the IP transmission quality of the SHV signal using a test line originating at BBC Television Centre and turning back at Glasgow, about 500 km to the north.
May	NHK, RAI	Connection of RAI DVB-S2 modems and an NHK codec via a TS divider / combiner, and testing of the SHV transmission over that system.
June	NHK, RAI, Eutelsat	Testing of the SHV signal satellite transmission quality with the transponders of the Eutelsat Telecom 2D satellite and Atlantic Bird No. 3.
August	NHK, the BBC, Siemens, C&W	Testing the stability of the SHV signal transmission using the line between London City Hall and the Amsterdam Rai Centre that would be used at IBC.

During IBC, engineers from the various organizations cooperated in London, Turin and Amsterdam to conduct the transmission experiment (*Figs 8, 9*).



Figure 8
Transmission site in London



Figure 9
Transmission site in Turin



Figure 10
OB production on the roof of London City Hall



Figure 11
The 275-inch screen in an Amsterdam theatre

Production

The Super Hi-Vision materials were produced in London by a team that included members from NHK, SIS, Siemens and the BBC. The team used a SIS microphone array and other such equipment along with the NHK Super Hi-Vision equipment (*Fig. 10*). A BBC producer and NHK technical staff operated the press showing in the NHK Theatre at the Rai Centre in Amsterdam.

Exhibition

Demonstration content

The international transmissions were presented on a 275-inch screen in a 50-seat Amsterdam theatre (*Fig. 11*). The transmitted content is described below.

IP transmission experiment

The camera and microphones were set up at London City Hall (*Fig. 12*). Tower Bridge and other city scenery viewable from the City Hall were shot by the camera (*Fig. 13*). The video was compressed by MPEG-2 and transmitted to Amsterdam. The images were shown in the theatre, where the inter-



Figures 12
Location of camera and microphones at City Hall in London



Figure 13
View of Tower Bridge from the Super Hi-Vision camera position



Figure 14
Outside the NHK theatre in Amsterdam



Figure 15
Entrance to the NHK theatre in Amsterdam

action between the Master of Ceremonies and the City Hall reporters was enjoyed. It was also continuously shown on a 62-inch 4k display, placed outside the theatre (Fig. 14).

Satellite transmission experiment

The video from a server, set up in Turin, was compressed by H.264 and transmitted via satellite for presentation in the Amsterdam theatre. It was also shown on a display composed of four 56-inch 4k displays set up near the theatre entrance (Fig. 15) and on a 56-inch 4k display at the EBU Village (Fig. 16).

Uncompressed content

The content compressed with MPEG-2 or H.264 was presented in the theatre, but to experience the true quality of Super Hi-Vision, uncompressed content was also presented. Furthermore, a video called “The Making of Super Hi-Vision” was presented at the press showing, along with still images comparing the pixel densities from those of standard TV up to Super Hi-Vision.



Figure 16
Super Hi-Vision demo at the EBU Village



Figure 17
Super Hi-Vision demo at the Eutelsat booth

An uncompressed Super Hi-Vision programme was also shown at the Eutelsat booth on a 56-inch 4k display (Fig. 17).

Results

The demonstration went smoothly throughout the duration of the exhibition, with no major complaints or problems. Also, the annoyingly frequent rain in London during the preparation period gave way to marvellously clear skies during the five days of the exhibition, and excellent views of London from City Hall were shown. We were convinced that most visitors to the show in Amsterdam enjoyed watching stunning live images and sound from London.

One visitor who saw the live video from London on the 62-inch display even made a phone call to an acquaintance seen walking on Tower Bridge to tell them to face the camera at City Hall !



Figure 18
The press showing at IBC



Figure 19
Dr Nagai, managing director of NHK (left) and Lord Digby Jones (right)

The Super Hi-Vision exhibit was a big attention-grabber at this year's IBC. At the press showing before the opening to the general public, there were more than twice as many press members as available seats in the theatre (Fig. 18). Several TV crews attended and videotaped the show.

5180 persons, including VIPs from various countries, visited the NHK Theatre and experienced Super Hi-Vision. One such visitor was Lord Digby Jones, British Minister of State for Trade and Investment (Fig. 19).

Visitors offered the following praise.

“I should congratulate you on this system’s very good quality and very impressive transmission capabilities, combining satellite delivery with fibre delivery. With that level of resolution and audio quality, I can see that it’s not just for entertainment but for educational purposes, for medical purposes, for a whole range of possibilities.”



Figure 20
IBC award ceremony

“ It was a wonderful demonstration. The content, too, was impressive. Seeing is believing. Please do a demonstration in our country, too. ”

“ The Super Hi-Vision show was thoroughly enjoyable. This is NHK setting the blueprint for the future, as you did with HDTV many years ago. ”

The success of this, the world's first international Super Hi-Vision transmission experiment, earned the Special Award from IBC (Fig. 20).

Future development (NHK's short-range research target)

At IBC-2006, NHK demonstrated a Super Hi-Vision camera and other equipment in our booth and, in the Super Hi-Vision theatre, we presented a Super Hi-Vision programme and live images that were captured at the convention site. The Super Hi-Vision signals were transmitted over optical fibre links. All equipment and transmission lines were set up within the Rai Centre.

With the success of this experiment at IBC-2008, the transmission of Super Hi-Vision signals has made a great stride forward from the 2006 demonstration.

What remained unchanged, however, were the camera and the display. We used the dual-green technology for both. For those who are not familiar with the dual-green system, it uses four imaging devices with 8 million pixels, two of which are used for the green channel and the remaining two are used for the red and blue channels. This means the cameras and the displays do not have the full resolution of the Super Hi-Vision system. Imaging devices with 33 million pixels were not available when the cameras and displays were developed.

Another important point is that the display device used for both demonstrations was a projector, not a direct-view display.

This clearly points the way to our next research targets, that is, the development of a full-resolution camera and a direct-view display. We will develop a prototype full-resolution camera with three 33-million-pixel image sensors by early 2011. We expect that display manufacturers will develop a flat-screen display with the full pixel count by 2011, as well. Furthermore, we will develop a full-resolution projector by the end of 2009.

By developing such cameras and direct-view displays, we can provide people with the first experience ever to see Super Hi-Vision images with full resolution in a home viewing environment. We believe this advance will be indispensable for determining the signal parameters of future broadcasting.

Besides developing the cameras and displays, we are developing compression techniques. A video bitrate of 130 Mbit/s was used for this year's IBC transmission experiment via satellite. We will be able to compress the Super Hi-vision signal to 90 Mbit/s by early 2010. Hopefully, we can conduct a transmission experiment over a single transponder of a broadcasting satellite around 2011.

Conclusions

This historic Super Hi-Vision demonstration at IBC-2008 was a resounding success. The progress made by it can be summarized as follows:

1) Participants

Two years ago, NHK and Japanese companies formed a team to bring Super Hi-Vision to Amsterdam. This year, NHK, the BBC, RAI and the EBU teamed up to accomplish the first international transmission of Super Hi-Vision signals with the cooperation of network operators and equipment manufacturers. The effort to develop a future television system has spread from Japan to Europe.

2) Transmission technologies

In 2006, signal transmissions were limited to within the convention site. This year's IBC demonstration involved the world's first international transmission of Super Hi-Vision signals over an ultra-broadband IP network and via satellite. This advance is due to improvements in signal compression, IP and satellite transmission technologies.

It is our responsibility to convince broadcasters, viewers, equipment manufacturers and network operators across the globe that Super Hi-Vision is not just a dream, but a real future television



Yoshiaki Shishikui received B.Sc., M.Sc. and Ph.D. degrees in electrical engineering from the University of Tokyo, Japan, in 1981, 1983 and 1997, respectively. He joined NHK (Japan Broadcasting Corporation), Tokyo in 1983. Since 1986 he has been with NHK STRL (Science and Technical Research Laboratories), where he has been engaged in research on digital signal processing, picture coding, HDTV broadcasting systems, IPTV systems and advanced data broadcasting systems.

Dr Shishikui is now a senior research engineer and the leader of the advanced services research group at NHK STRL. From 2001 to 2003, he was with NHK Engineering Services Inc., where he helped to develop video archives and video-on-demand systems. He has been a part-time instructor at several universities in Japan and has been actively involved in standardization activities at SMPTE and ISO-IEC (MPEG).

Dr Shishikui served as Associate Editor for IEICE Transactions D (Japanese) from 1997 to 2001. He received the Best Paper Award from ITE Japan. He is a member of both ITE Japan and IEICE Japan.

Yoshihiro Fujita received B.Sc. and Ph.D. degrees in electronic engineering from the University of Tokyo, Japan, in 1976 and 1998, respectively. He joined NHK (Japan Broadcasting Corporation), Tokyo, in 1976. He has more than 25 years' research experience at NHK STRL (Science and Technical Research Laboratories). He started research on advanced imaging systems for HDTV and post HDTV. He holds several awards from ITE Japan for developing Dual-Green camera systems. At present, he is an executive research engineer and is engaged in standardization activities and coordination of international collaborative research.

Dr Fujita currently serves as chairperson of the Digital Broadcasting, R&D DTB group at ARIB (Association of Radio Industries and Businesses) Japan and is a member of the IEEE, IEICE and ITE Japan.



Keiichi Kubota joined NHK (Japan Broadcasting Corporation) in 1976. From 1979 to 1980, he was a visiting engineer at the CBS Technology Centre in the USA. Since August 1980, he had been with the Science and Technical Research Laboratories of NHK, working in the areas of satellite transmission systems for HDTV, signal processing for HDTV and subjective assessment of HDTV picture quality.

From 1989 to 1993, Dr Kubota was the Senior Scientist at NHK's New York Office. During this period he participated in various HDTV standardization activities in SMPTE, ATSC and the FCC Advisory Committee on ATV Service. In 1993, he was transferred to NHK Laboratories as the Senior Research Scientist and, later, the Deputy Director of Advanced Television Systems Research Division, where he was in charge of research activities in digital coding of HDTV. In 1996 he was transferred to the Planning Division of the Engineering Administration Department as the Senior Associate Director, where he was responsible for starting NHK's digital satellite broadcasting service.



From 2001 to 2005, Keiichi Kubota was Director of the Planning and Coordination Division, and then the Deputy Director of the Laboratories. From 2005 to 2007, he was in charge of the nationwide rollout of NHK's terrestrial digital broadcasting services, serving as Engineering Controller for the Engineering Administration Department. Currently, he is the Director-General of the NHK Science and Technical Research Laboratories.

Dr Kubota received his B.Sc. and Ph.D. degrees from the University of Tokyo in 1976 and 1987 respectively, and is a fellow of SMPTE and IEEE.



Figure 21
The SHV teams involved in the IBC-2008 demos: in Amsterdam (*top*), in London (*left*) and in Turin (*above*).

system, and we think we can meet this responsibility by showing everyone real Super Hi-Vision images.

The success of this demonstration rests on the contributions of many organizations, including the IBC, the Rai Centre in Amsterdam and the City of London, and the devoted efforts of many support staff members as well as on the work of the eight partner organizations. The authors would like to conclude by thanking everyone who was involved in this project.