

## Greeting

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The NHK Science and Technology Research Laboratories (NHK STRL) is the sole research facility in Japan specializing in broadcasting technology, and as part of the public broadcaster, NHK, it has the role of leading Japan in broadcasting technology and contributing to building a rich broadcasting culture.

To fulfill this role, STRL is conducting a wide range of research and development activities with an emphasis on research toward the realization of three important objectives: media for enhanced-reality spatial reproduction, useful and universal services, and high-level content-production environments. We are also proactively engaging in standardization efforts for the technology we have developed. Standardization is essential for using new technology in television production to create better programs and to provide new services.

The 2008 fiscal year was the first year under our new policy for research and development called "YOU". In accordance with this new policy, we are accelerating R&D on future broadcast services such as Super Hi-Vision and three-dimensional television. We are also resolving difficulties related to the final switchover of terrestrial television broadcasting from analog to digital in 2011 and strengthening cooperation with broadcasting and research organizations in various countries by promoting international collaborations and dissemination of research results.

It is my hope that this annual report will be helpful to you in understanding STRL's research and development activities, for building collaborative relationships toward new research and development, and for making use of our research and development results.

I would like to express my gratitude and request your continued support and cooperation in the future.



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# Accomplishments in 2008

STRL2008

2008	<b>Apr.</b>	<ul style="list-style-type: none"> <li>Super Hi-Vision, High-speed image capture, and Hi-Vision HARP camera exhibited at NAB 2008 in Las Vegas.</li> </ul>	
	<b>May</b>	<ul style="list-style-type: none"> <li>62nd NHK STRL Open House held; theme: "The Never-ending Evolution of Television"</li> <li>Mobile website introducing NHK STRL opened.</li> </ul>	
	<b>June</b>	<ul style="list-style-type: none"> <li>Super Hi-Vision exhibited for the first time in Asia, together with technology related to digital terrestrial broadcasting, at Broadcast Asia 2008 in Singapore.</li> <li>ITU Secretary-General Toure inspects the latest technology at NHK STRL.</li> </ul>	
	<b>Sep.</b>	<ul style="list-style-type: none"> <li>International transmission test of Super Hi-Vision conducted in cooperation with European broadcasters receives special IBC Award at IBC 2008 in Amsterdam.</li> <li>Low-latency, multipath equalization equipment developed, enabling low-cost relay stations for digital terrestrial broadcasting.</li> <li>Digital terrestrial broadcasting technology exhibited at ITU-sponsored Telecom Asia 2008 in Bangkok.</li> <li>Super-high-speed, high-sensitivity camera and emergency earthquake report system exhibited at CEATEC 2008.</li> </ul>	
	<b>Oct.</b>	<ul style="list-style-type: none"> <li>"NHK STRL Plaza" events held at nine broadcasting stations throughout Japan (till Feb. 2009).</li> <li>STRL research results, including a Super Hi-Vision screening, at a fair commemorating 80th Anniversary of the Kumamoto station.</li> </ul>	
	<b>Nov.</b>	<ul style="list-style-type: none"> <li>NTT and STRL conduct experiment on transmitting a 10-Gbps signal multiplexing six uncompressed Hi-Vision signals over a 120-GHz-band wireless link.</li> </ul>	
	<b>Dec.</b>	<ul style="list-style-type: none"> <li>Wireless mobile camera and HARP camera used on the 59th Kohaku Uta Gassen New Year's music show.</li> <li>Public viewing of Super Hi-Vision held in meeting hall next to Kohaku Auditorium.</li> </ul>	
	2009	<b>Jan.</b>	<ul style="list-style-type: none"> <li>Virtual-experience experiments involving high-quality, live sound space reproduction conducted at Tokyo Opera City in cooperation with the Tokyo Philharmonic Orchestra.</li> </ul>

## Activities during 2008

Our current mid-term vision of the future is called "YOU". Details about it were presented at the 2008 Open House. The plan calls for a new approach to R&D, one that emphasizes technology that will give the viewer the feeling of being in the scene depicted on screen or enables them connect with the broadcast in new ways. It also outlines the final stages of the country's switch from analog to digital in 2011, promotes measures to make the business of broadcasting more environmentally friendly, and calls for the development of new technology that will contribute to making our society safer and more secure.



IBC 2008 Special Award Ceremony



Rehearsal for Kohaku Uta Gassen

Super Hi-Vision and digital terrestrial broadcasting technology were exhibited at overseas events, including NAB2008 and Broadcast Asia 2008. In particular at IBC2008, NHK, the BBC, RAI, and EBU formed the Broadcast Technology Futures Group (BFT) and performed international transmission experiments on Super Hi-Vision over IP and via satellite. Over 5,000 visitors, including dignitaries from various countries, attended the Super Hi-Vision theater at IBC and viewed the experimental transmissions. The viewing was evidence of how Super Hi-Vision R&D has progressed through international cooperation. STRL received a special IBC prize for these international transmission experiments. The results of STRL research and development have been used in countless television programs. In particular, our latest Hi-Vision wireless camera and ultra-sensitive HARP camera were put to good use in NHK's New Year's Song Festival, Kohaku Uta Gassen. These cameras enabled new kinds of camerawork on stage during a performance and in the absence of energy-consuming stage lights. Moreover, this year was the third in which a live Super Hi-Vision feed from the festival could be publicly viewed in the NHK Fureai Hall next door to the venue. The Fureai Hall audience's experience was enhanced by

the use of a camera with a ten-fold increase in sensitivity and rear-cancelling microphones. Beijing Olympics programming was another very successful use of our technology. In this case, our robotic cameras and advanced production technology for integrating computer graphics with studio camerawork were used to present athlete profiles and competition results during the studio portions of the Olympic broadcasts. Research and development related to the switchover to digital terrestrial broadcasting in 2011 also progressed, with developments such as same-channel interference cancelling technology for home receivers.

## NHK STRL Open House

The 2008 NHK STRL Open House was held from May 22 through May 25 on the theme of "Changing Television through the Power of Technology." It consisted of 23 exhibits on STRL research results, lectures from important figures in the world of broadcasting, and presentations and posters displays from our researchers. Over 21,000 visitors came to the open house.

Research results were exhibited in five zones:

1. The "Cultivating Broadcast Media" zone exhibited the latest research results in camera, transmission, and compression technology for Super Hi-Vision broadcasting as well as research on new digital satellite broadcasting services, broad support for digital terrestrial broadcasting across the country, and technology for creating interesting and convenient new services.
2. The "Enhanced Reality, Spatial Reproduction Media" zone exhibited research on the ultimate in audio and video reproduction; research on Super-Hi-Vision and 3D video, to create media that convey affective sensations, or "Kandoh" in Japanese, and on human science.
3. The "Useful and Universal Services" zone exhibited service schemes combining broadcasting, communications, and storage media to provide sophisticated but easy-to-

use media suited to each viewer.

4. The "High-Level-Content Production Environments" zone exhibited technology for efficiently producing rich program content, whether for studio or for on-site support.
5. The "Use and Expansion of Broadcast Technology" zone introduced applications of the latest broadcast technology to fields such as medicine, science, industry, education, welfare, disaster prevention, and public services.

There were also various programs designed to suit the interests of the wide variety of attendees, including poster displays explaining the details of our research, guided tours of the exhibits by researchers, and experiential exhibits intended for children to get hands-on experience of broadcast technology.

## NHK Patents

Licensing of all patented technologies required for digital cable TV broadcasting (CATV) through patent pooling began in October, 2008, and together with the patent pool for ARIB standard patents, we have established licensing schemes for all digital-broadcast receiver formats. NHK STRL had an exhibit at the "Patent Solution Fair 2008," hosted by the patent office in October to promote distribution of patented technology, as well as at the "Effective Patent Solutions YOKOHAMA 2009" patent distribution fair, hosted by the city of Yokohama in February. Through these activities, we promoted our technologies and helped to return the fruits of our research and development back to society.

## For Our Viewers

Last year, we provided tours of our latest broadcast technology to many visitors from around Japan and abroad. To promote an understanding of our research and activities among the public and private industry, we exhibited our research results at events at broadcasting stations throughout the country, at the 80th Anniversary Fair of NHK's Kumamoto Station, and at the CEATEC Japan convention. We also opened a new mobile website; like the regular STRL Website, the new mobile site introduces STRL and provides the latest information about its research and development projects.

# Research on Enhanced Reality and Spatial Reproduction Media

## OUTLINE

Our research on "Enhanced Reality and Spatial Reproduction Media" has the goal of creating media that will convey an enhanced sense of reality and presence in comparison with today's media. Viewers will feel as though they are immersed in the world depicted on the screen. In order to make this possible, we must study audio, video, coding, and transmission technologies, as well as pursue international standardization, conduct research from a human sciences perspective and develop new devices.

### 1.1 Super Hi-Vision research

Super Hi-Vision (SHV) research has progressed in the areas of formats, cameras, displays, video coding, and satellite transmission methods.

Regarding the SHV format, we are continuing to study the visual characteristics of super-high-resolution images in order to finalize the video aspect of the format.

Regarding SHV cameras, we are experimenting with three 33-Megapixel image sensors and working to complete a full-resolution SHV camera with a resolution of 7680×4320 pixels per frame for each of the red, green and blue channels.

With respect to SHV displays, we have built a wide-dynamic-range projector using a double modulation scheme to show blacker blacks, and by exploiting knowledge of the visual characteristics of the human eye, we achieved a display with the full-resolution quality by using 33 megapixel elements in the second stage of modulation and elements with fewer pixels in the first stage.

Regarding video coding, we reduced the noise of the AVC/H.264 video coder by using a pre-filter and reducing discontinuities at image partitioning boundaries.

Finally regarding satellite transmission methods, we continued to study digital satellite broadcasting of SHV in the 12-GHz band, as well as simultaneous broadband satellite transmission of multiple SHV programs using the 21-GHz band.

We also presented proposals for standardization of SHV to the ITU-R and SMPTE.

### 1.2 Three-dimensional television research

We are continuing with research on integral 3D television, a form of 3D television that does not require special glasses or other apparatus, and have developed an image processing method to control the depth of the generated 3D images.

### 1.3 High-Presence audio systems research

In order to create SHV for home use, we are developing signal-processing technology for preserving the sense of presence of 22.2 multi-channel audio when it is presented through a smaller number of speakers.

We are researching thin, flexible speakers, not restricted by conditions or form of the installation environment, for SHV home receivers and flexible displays. We are also researching a highly directional microphone with well-suppressed rear response for SHV and for program production in the presence of background noise.

We made technical contributions to the ITU-R, SMPTE, and MPEG for standardization of 22.2 multi-channel audio.

We performed experiments with the Tokyo Philharmonic Orchestra at the Tokyo Opera City Concert Hall in January 2009, as part of our research on live transmission and high-quality reproduction of sound fields from orchestras or other concert-hall performances at a separate location.

We are also continuing research into the relationship between sound and deeply emotional feelings (kandoh in Japanese) to provide a new perspective on evaluating sound systems.

### 1.4 Research on "Enhanced-Reality, Spatial-Reproduction Media"

We are researching elemental technologies for plasma display panels (PDP), low-voltage protective film materials, and panel driver methods for an SHV display for household use.

We are also studying cathodoluminescent and electroluminescent materials for field emission displays (FED) and inorganic electroluminescent (EL) displays.

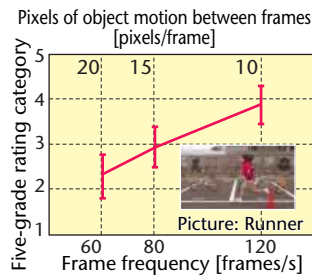
SHV will require a high-volume, high-speed storage medium, so we are researching a high-definition, high-speed spin-injection light-modulation device using spin-injection magnetization reversal technology and the magneto-optical effect that can rapidly control magnetization of magnetic material on microscopic scales. We are also researching multiplexing and wavefront compensation techniques for holographic recording.

## 1.1.1 Super Hi-Vision

### Format

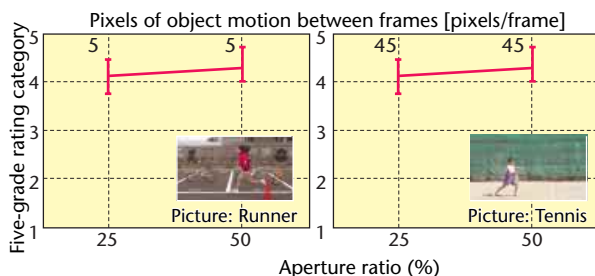
We are continuing research related to the visual characteristics of super-high-resolution images, to gain knowledge for finalizing the Super-Hi-Vision (SHV) video format, which is on the agenda for standardization at ITU-R (International Telecommunications Union - Radiocommunication Sector), and SMPTE (the Society of Motion Picture and Television Engineers).

In 2007, it was shown that an accumulation time of less than 1/300seconds would be needed to keep motion blur within acceptable limits. Although the accumulation time can be sufficiently shortened by reducing the shutter-open time, without increasing the frame frequency, undesirable stroboscopic effects similar to multiple-strobe exposures appear. In 2008, we studied these effects by varying the frame frequency and aperture ratio of sport videos. The speed of the object focus point was between 20 and 180deg/sec at the standard viewing distance. we conducted a five-grade-rating subjective evaluation of image degradation due to the stroboscopic effect by setting the reference frame frequency to 240Hz and aperture ratio to 100% varying and other parameter values. Example results with fixed shutter times are shown in Figure 1 (Runner).



**Figure 1. Subjective evaluation of strobe effect (fixed shutter-open time)**

The results show that as the frame frequency increases to 240Hz, image degradation due to the stroboscopic effect decreases. Other evaluation images produced the same result. The evaluations with the fixed frame frequency and variable aperture ratio (Figure 2) showed that the image degradation increases as the aperture ratio decreases when the object is moving quickly (Figure 2 right, tennis, 180deg/s), but there is little image degradation if the object is moving slowly (Figure 2 left, runner, 20deg/s). Considering how far the object moves between frames, these results indicate that there is 45pixels/frame of motion in the tennis clip, but only 5pixels/frame of motion in the runner clip, so it appears that the stroboscopic effect is not apparent unless there is a certain amount of movement of the object between frames. Considering that there was degradation with a fixed shutter-open time and 10 pixels/frame of motion, object motion in the range of 5 to 10 pixels/frame would not produce a stroboscopic effect.



**Figure 2. Subjective evaluation of strobe effect (fixed frame frequency: 240Hz)**

### Camera

We developed an experimental color camera with three 33-mega-pixel image sensors as a major step in our development of a full-resolution SHV camera with a resolution of 7680×4320 pixels per frame on each of the red, green, and blue channels.

A newly developed fixed-focal-length lens and a color separation prism have a 2.5-inch optical format to match the active area of the image sensor (29.1mm×16.4mm).

We also developed a signal processing unit and a signal interface. The signal processing unit takes the high-speed, video data of 72Gbps from the three image sensors, processes them, and transmits them in real time. The signal interface to connect devices uses a 12-channel pluggable optical module and 8B/10B encoding technology.

The equipment (Figure 3) achieved a response of approximately 20% at 4320 TV lines, the limiting resolution frequency for the SHV system. Sensitivity was 2000lux, and S/N was 45dB at F-number 4.



**Figure 3. 33-mega-pixel 3-sensor camera test filming equipment**

In other work, we evaluated the image quality of a digital zoom device (development started on it in FY2006) that converts part of the SHV video into Hi-Vision (HDTV) video. We added a controller and improved operability. We also improved color fidelity of a single-chip color Hi-Vision camera which uses the image sensor developed for SHV cameras in 2007.

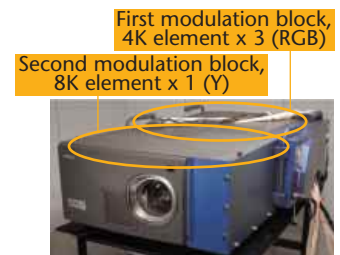
### Program production

We verified the two-hour capacity of the SHV disk recorder and the operation of the SHV video switcher developed in FY 2007, and we used them during the live relay of the Kouhaku Uta Gassen (New Year's Song Festival) program to the Fureai Hall presentation site.

We also developed a full-resolution SHV frame memory (I/O: HDMI 16-channel, Rec/Playback time: approx. 15s, Video signal: 7680×4320 pixel RGB, 12-bit 60Hz progressive).

### Displays

We improved the high-dynamic-range projector by adapting the luminance panels in the second modulation block and the driver circuits for 7680×4320 pixels (Figure 4). This projector was exhibited at the NHK STRL Open House and at a trade show (CEATEC 2008) and viewers were impressed with its still-image quality. The double-modulation architecture has lower resolution (3840×2160 pixels) for hue and saturation, and higher resolution (full SHV resolution, 7680×4320) for luminance, similar to human vision. We will improve the projector so that it can display motion images, and we will continue to improve its image quality.



**Figure 4. Super Hi-Vision high-dynamic-range projector**

We will also develop a projector using three of the 7680×4320 pixel panels described above to make a full-resolution SHV display.

## 1.1.2 Super Hi-Vision high-compression coding

The Super Hi-Vision (SHV) high-compression codec system uses the AVC/H.264 scheme (ISO/IEC 14496-10 Advanced Video Coding and ITU-T H264) (Figure). In cooperation with Fujitsu Laboratories, we developed a new coding algorithm that allocates the bit rate according to the luminance of the SHV video signal. The new algorithm reduces periodic image flicker, and as a result, improves the image quality. We also developed a noise-reduction pre-filter to further improve image quality. This pre-filter helps to lower the bit rate and makes it possible to reduce artifacts due to low-bit-rate coding. The current codec system divides SHV video into sixteen HDTV parts and processes them using sixteen HDTV encoders. In some cases, the boundaries between HDTV parts become visible because the



Super Hi-Vision video coding and decoding equipment

luminance values do not match at the boundaries between parts. To cope with this issue, we developed an adaptive post filter that reduces discontinuities at the boundaries of the decoded image.

To improve the AVC/H.264 coding, we devised a method to improve the quality of critical images. Specifically, this method uses motion vector values to identify the degree of difficulty of coding in a frame and revises the quantization values.

We participated in studies on video coding methods for advanced digital satellite broadcasting and HDTV contribution AVC/H.264 codecs. We contributed to SHV satellite transmission experiments and studies estimating the bit rates required for 1080/60P and 2160/60P broadcasting, the tandem-connection characteristics for AVC/H.264 codecs, and bit rates required for HDTV contribution signals.

We also collaborated with the British Broadcasting Corporation (BBC) on using Dirac video coding technology for SHV.

## 1.1.3 Super Hi-vision transmission via satellite

We performed various studies using 12 GHz and 21 GHz-band satellites for broadcasting Super Hi-Vision (SHV).

We studied the feasibility of advanced digital satellite broadcasting as a way of transmitting SHV over a 12-GHz-band satellite. We studied multi-level APSK modulation schemes, including 16APSK and 32APSK, as means of transmitting a high-bit-rate signal on a limited bandwidth. In experiments using 32APSK modulation, we were able to transmit an SHV signal that was compression coded to 120 Mbps and occupying bandwidth of 34.5 MHz.

In order to transmit multiple SHV programs to households at the same time, we are continuing our studies of satellite broadcasting systems in the 21-GHz band. The frequency allocation plan specifies a 600-MHz bandwidth from 21.4 GHz to 22 GHz for satellite broadcasting. This band is much wider than the 12-GHz band, so multiple SHV signals can be transmitted with time-division multiplexing on a single carrier. To verify the feasibility of hardware for wideband transmission of SHV signals and to evaluate the severity of impairments affecting the satellite channel, we are developing a 300-MHz-class modulator-demodulator prototype. In 2008, we added a new error correction function using low-density parity check (LDPC) code to the prototype. We plan to use this equipment in SHV transmission experiments using the WINDS satellite in 2009.

The 21-GHz band is significantly affected by attenuation due to rainfall, and we are studying the following three

methods for dealing with this issue.

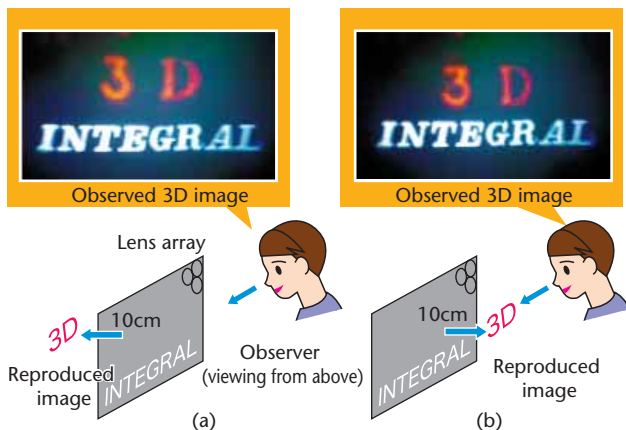
1. A phased array antenna can be used to control the emission pattern of the signal. When the weather is clear, all areas receive a uniform signal, but when there is rain, the pattern is adjusted to amplify the signal in areas receiving rain.
2. A multi-horn antenna can cover Japan with eight beams and adjust the power supplied to each beam by using multi-port amplifiers. The power to beams covering regions where there is rain can be selectively increased.
3. A mirror antenna with a modified reflective surface can be used to form an emission pattern that provides relatively higher gain for the south-western parts of Japan, which receive more rainfall on average, thereby achieving uniform year-round service rates over the whole country.

We compared these three methods by drawing up detailed satellite-system designs and comparing them in terms of cost, weight, power requirements, and estimated service-time rates.

## 1.2.1 Three-dimensional television

We are researching a spatial imaging-type integral three-dimensional (3D) television based on the principle of integral photography. This system does not require special glasses, and it can present 3D images to a viewer moving horizontally or vertically. To improve quality of the 3D images, we need to have high-definition images, so we are developing the required elemental technologies using Super Hi-Vision (SHV) cameras and projectors.

In FY 2008, we developed an image processing method allowing arbitrary control of the depth position of the reproduced 3D images. Light rays from the elemental



**Controlling the depth-position of the reproduced Integral 3D image**  
The "3D" text is displayed

(a) 10 cm behind or (b) 10 cm in front of the lens array.

images and the lens array are computed and then recomputed according to the desired depth position, generating new elemental images for the 3D display. The method allows the depth position of the 3D image to be adjusted according to the content and size of the display (Figure).

When using a SHV projector for the integral 3D display system, even a small amount of distortion in the elemental images significantly deforms the 3D image. Therefore, we analyzed the distortion characteristics of the projected image and their relation to deformation of the 3D image. The 3D image quality was improved by applying geometric corrections to the elemental images and minimizing deformation of the 3D image.

Note that this research on integral 3D TV was done as part of the "Multi-parallel & spatial imaging three-dimensional television system R&D" project of the National Institute of Information and Communications Technology (NICT).

We also continued our collaborative research with NICT on electronic holography. In FY 2008, we converted integral photography images into holograms, and displayed them as holograms with a viewing angle of 15 degrees by using experimental display equipment.

\*1 Integral Photography: A method able to reproduce three-dimensional images by using a lens array for both imaging and displaying.

\*2 Elemental images: The images captured using the lens array.

\*3 Lens Array: An array of many small lenses arranged in a panel.

## 1.3.1 Acoustic devices

### Flexible speakers

We are conducting research on thin, flexible loudspeakers that are not limited by the installation circumstances of 22.2 multichannel sound for Super Hi-Vision home receivers and portable flexible displays. In FY2008, we developed a speaker made from a rubber-like elastomer material and having flexible electrodes that expand and contract freely. The speaker is driven by a sound signal superimposed over a DC bias voltage.

As a result of preliminary tests, we selected thermoplastic polyurethane for the elastomer material and polyethelenedioxythiophene for the electrodes. We created a prototype omni-directional loudspeaker using an A5-sized, 300- $\mu$ m-thick sheet of elastomer formed into a cylindrical column (Figure 1). The maximum sound-pressure level was 75dB SPL at 1 kHz, and the harmonic distortion was -30dB or less relative to the fundamental response in the range over 800Hz. These results indicate that the design should present no problems in practice.



**Figure 1. Electro-active elastomer speaker**

### Microphones

We are continuing research on a narrow-angle directional microphone that suppresses the response to sound originating behind it, for program production in noisy environments and 22.2 multichannel sound applications. In FY 2008, the microphone was used in golf and soccer relays, and the conditions for suppressing the response to sound from behind was also clarified. We also performed 22.2 multichannel recording tests using this directional microphone and other microphones.

We created a smaller version of our unidirectional super-wide-range microphone prototype. The microphone can record sound up to 100kHz and is intended for applications such as next-generation broadcast services and archiving (Figure 2).



**Figure 2. Unidirectional super-wide-range microphone (second prototype)**

### 1.3.2 3D Audio

#### Research on television systems conveying a strong sensation of presence

##### - 22.2 Multichannel sound systems

In FY2008, we submitted contributions to various standards organizations within and outside Japan regarding the 22.2 multichannel sound system of Super Hi-Vision. The digital audio signal characteristics, channel labels, and channel map for the 22.2 system were standardized by SMPTE (Table 1, Figure 1). At MPEG, we submitted a revised proposal for MPEG2-AAC to handle 3D speaker placement for 22.2 multichannel sound coding. The revision has been accepted, and deliberation on it has begun. Also, we created a draft report called "Multi-channel sound technology for home and broadcast applications" for ITU-R's standardization efforts on multichannel sound systems above the level of 5.1-channel sound. In the working group established by ARIB to study sound systems for ultrahigh-resolution TV studios, we continued to study the proposed studio standards based on 22.2 multichannel sound.

We conducted R&D on production tools to raise the quality and ease the production of 22.2-channel sound content. In FY 2008, we developed a system for down-mixing 22.2 channel sound to other multi-channel formats and a portable 48-track simultaneous recording and playback system to monitor and record 22.2 channel sound, even outdoors.

##### - Advanced multichannel live sound reproduction system

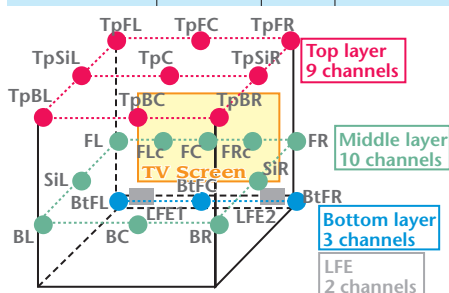
We are researching recording and reproduction methods for transmitting and reproducing the sound field created by, for example, an orchestral performance in a concert hall at a remote location. We conducted an experiment in transmitting a performance of the Tokyo Philharmonic Orchestra on January 29, 2009 at the Tokyo Opera City Concert hall and reproducing it in real time at a nearby recital hall. The music was captured on the orchestra's stage using 31 microphones, and it was reproduced in the recital hall on 21 speakers arranged in four rows. The measured impulse response of the concert hall was convolved with direct sound of the orchestra. The sound was then mixed with indirect sound from ten microphones set up in the performance hall and played back through 16 speakers surrounding the audience in the reproduction hall. This experiment verified that this method can capture, transmit, and reproduce an orchestral performance in real time and with high quality.

#### Research on spatial acoustic signal processing

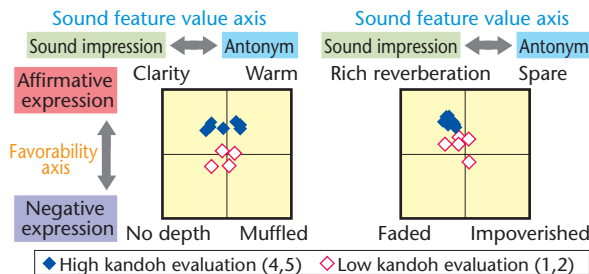
Super Hi-Vision receivers in homes of the future should have signal processing to reproduce 22.2 channel audio on fewer speakers, while preserving the sense of presence. In FY 2008, we developed the basic signal processing methods and performed subjective evaluations confirming that as long as the time-averaged acoustic intensity (average acoustic power passing through a unit area over one cycle) is kept the same at

**Table 1. 22.2 multichannel sound channel labels and mappings standardized in SMPTE2036-2-2008.**

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 center
2/2	4	LFE1	LFE-1
3/1	5	BL	Back left
3/2	6	BR	Back right
4/1	7	FLC	Front left center
4/2	8	FCR	Front right center
5/1	9	BC	Back center
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 center
8/2	16	TpC	Top center
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 center
11/2	22	BtFC	Bottom front center
12/1	23	BtFL	Bottom front left
12/2	24	BtFR	Bottom front right



**Figure 1. Overview of 22.2 multichannel sound channel labels and mappings standardized in SMPTE2036-2-2008.**



**Figure 2. Discrepancies in sound impression evaluation related to evaluation of kandoh.**

the sound reception point, the spatial impression of sound stays within an acceptable range, even when the number of channels is reduced from 22 to 10. We also advanced our research on personalizing the head related transfer function (HRTF) by developing a method for estimating the transfer function for all azimuth angles given the transfer functions for a small number of angles.

#### Research on acoustic perception models

We are continuing with our research studying the relationship between sound and "Kandoh" (which is Japanese for deep emotional feelings), to provide a new perspective on evaluating sound systems. In FY 2008, we investigated the factors affecting evaluations of kandoh and studied models of physical characteristics that seem to have good correlation with evaluations of kandoh.

We performed subjective experiments on the effect of sound quality and instruction on the kandoh evaluation. We found that as sound quality degrades, the perception of depth and rich reverberation also decrease. Also, instructions on the composition can also

change feelings like sadness. We also found that some impressions such as depth and rich reverberation have a high correlation with kandoh. To study words describing sound impressions in more detail, we selected word pairs with opposite meanings describing sound impressions (called the feature-value axis, e.g. clarity vs. warmth), and positive and negative impression word pairs used to indicate listener responses (called the favorability axis, eg. clarity vs. no depth or warmth vs. muffled) based on a survey. The psychological tests using these pairs (Figure 2) showed that differences in impression correlating to kandoh evaluations were more along the favorability axis than along the sound feature-value axis.

We are also studying mathematical models with acoustical analysis for estimating a sound image's "width", which is one of the impressions that correlated well with kandoh evaluations. We investigated the effects of time and frequency resolution in the analysis. We found a tendency for these physical values that are thought to be related to expanse and breadth of stereo imaging, such as the correlation between the two ears to correlate with subjective evaluations when the resolutions are high.

## 1.4.1 Plasma displays for Super Hi-Vision

We are continuing with our research on Super Hi-Vision (SHV) displays, including the elemental technology for plasma displays (PDPs), panel fabrication technologies, low-voltage protective layer materials, and panel driving methods.

Till now it has been difficult to achieve ultra-high-resolution PDPs because of decreased luminous efficiency, but new insight into the gas-discharge mechanisms of PDPs has indicated that higher resolution can be obtained by increasing the gas pressure. We achieved the 0.3-mm pixel pitch necessary for 100-inch diagonal SHV displays using a small PDP and successfully reproduced video images on a 6.5-inch diagonal PDP.

In FY2008, we used fabrication technology capable of handling our goal of a 100-inch-class panel and optimized the conditions for forming components such as barrier ribs and phosphor layers to make the pitch even finer. The result was an ultra-high-resolution 7-inch PDP prototype with a 0.285 mm pixel pitch (Figure).

The 7-inch PDP used a strontium calcium oxide (SrCaO) protective layer. We investigated the characteristics of this protective layer on 0.3mm pixel-pitch panels because such a layer was previously shown to be a way of lowering the discharge voltage on 0.66mm pixel-pitch panels. The investigation showed that the SrCaO protective layer allowed for a 25% reduction in driving voltage compared with the magnesium oxide (MgO) protective layer in general use

today.

A PDP basically has only two states of operation, ON and OFF, so it displays gradations by mixing multiple subfields with differing light-emission times within a single field. When the number of scanning lines increases, the addressing time for each line must be decreased, and it becomes increasingly difficult to achieve stable discharge. We found that, when using the sub-field method described above, even if multiple lines are driven at the same time with the same signal, image quality degradation can be controlled when mixing them to display gradations. We conducted subjective evaluations of this method for driving the display and verified it to be effective. Hence, we believe the method can reduce the cost and energy consumption of the displays.



Example of video image reproduced on 0.285 mm pixel-pitch ultra-high-resolution 7-inch diagonal PDP with SrCaO protective layer (Exhibited at the 2008 STRL Open House)

## 1.4.2 Nanophotonics

We are researching cathodoluminescence and electroluminescent phosphor materials for use in self-emissive field emission displays (FED) and inorganic electroluminescent (EL) displays.

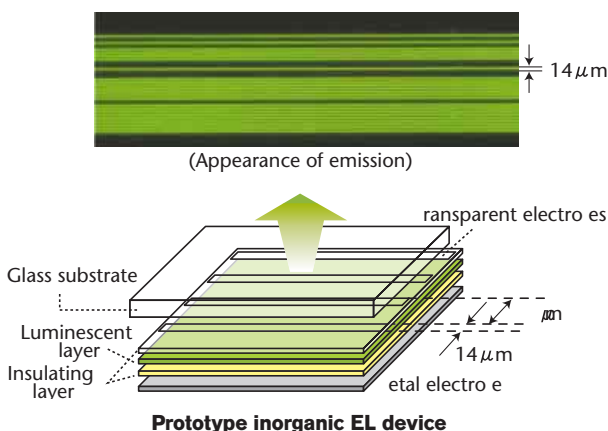
To achieve high resolution with cathodoluminescence phosphors, we are attempting to form high-quality SrGa<sub>2</sub>S<sub>4</sub>-type phosphor thin films of 1 μm thickness or less. We used molecular beam epitaxy (MBE) to form thin films with a SrGa<sub>2</sub>S<sub>4</sub>:Eu green phosphor and the SrGa<sub>2</sub>S<sub>4</sub>:Mn,Ce red phosphor developed in FY2007. We evaluated the cathodoluminescence characteristics of these phosphors and found that they had acceleration voltages of 10 kV or

less, which make them suitable for use in FEDs.

We confirmed that the excitation of luminescent centers of SrGa<sub>2</sub>S<sub>4</sub>:Mn,Ce is due to holes rather than electrons. This sort of excitation is potentially the basis of a new high-luminance, high-efficiency luminescence mechanism. The phosphors SrGa<sub>2</sub>S<sub>4</sub>:Eu, EuGa<sub>2</sub>S<sub>4</sub>, BaAl<sub>2</sub>S<sub>4</sub>:Eu also have hole-based excitation mechanisms. These discoveries will be useful for improving the performance of electroluminescent phosphors.

To investigate the possibility of increasing the resolution of inorganic EL displays, we created a prototype device with microscopic electrodes and evaluated its emission characteristics. We confirmed emissions with electrode widths of 14 μm (Figure), as required for 2-inch-class Hi-Vision monitors. In the future, we will create prototype devices with smaller electrode widths and spacings.

We began development of thin-film phosphor production methods that put nanoparticles (particles with diameters of nm order) on a substrate and transform them into a thin film. We created thin films by depositing nanoparticles on a glass substrate by using spin coating. When applied to inorganic EL devices, the thin films showed a weak emission. This experiment confirmed that emission is possible.



### 1.4.3 Optical-spin devices

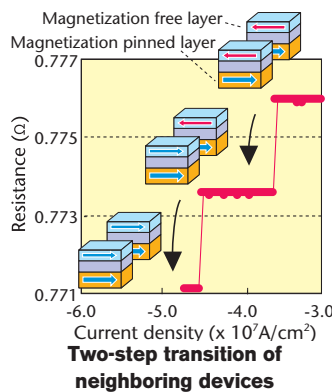
We are working on spin-injection light-modulation device combining spin transfer torque switching (STS) technology, which is used to reverse the magnetization of microscopic magnetic materials at high-speed, with the magneto-optical effect. In FY2008, we improved the characteristics of the light modulation device and did a study on using multiple devices for one pixel in order to show gray scale.

We fabricated prototype sub-micron light-modulation devices using a cobalt-iron-boron alloy in the magnetization free-layer (the light-modulation layer). We produced a sample having two adjacent devices with an intervening gap of less than  $1\mu\text{m}$  and measured its STS effect. The results of the measurements (Figure) show a two-step transition of resistance in which one of the free layers in the two devices was switched by smaller current densities compared with the other free layer. This indicates a stable intermediate state in which only one of the free layers switches, a state which could be very useful for displaying gray scale. These results match those of a micromagnetic simulation done in FY 2007, indicating that the simulation model is effective for analyzing the behavior of the actual devices.

To improve the characteristics of spin transfer torque switching, we studied materials for use in the magnetically

pinned and free layers. We introduced a layer of terbium-iron-cobalt alloy with perpendicular magnetic anisotropy for the magnetically pinned layer and controlled the coercivity of elements by changing their content and thickness. In the magnetization free layer, we used a platinum/cobalt multi-layer film because its magneto-optic effect is also large for blue wavelengths and its magnetic properties do not degrade with microscopic manufacturing processes. A transparent indium-zinc-oxide electrode was formed on the upper electrode of the spin-injection device prototypes using these materials, and the magnetic Kerr rotation at a wavelength of 405 nm was measured. The measured Kerr rotation was approximately three times that of free-magnetization layers using conventional gadolinium-iron alloy. We have also begun to evaluate magnetic materials using a new pump-probe method in order to search for and improve the characteristics of materials suitable for light modulation devices.

Our quantum-dot research has the goal of realizing multi-value memory using the various internal states of nano-structured magnetic materials. We evaluated cobalt/copper and nitrogen/copper interfaces, which should be able to be used to make magnetic quantum dots, by using highly sensitive non-linear optical vibration spectroscopy to detect the magnetically induced state of microscopic regions.



### 1.4.4 Holographic data storage technologies

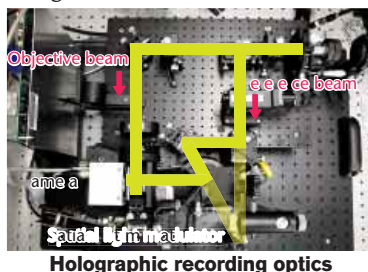
We are studying holographic data storage technologies that may one day be used in large-capacity, high-speed recording systems for Super Hi-Vision. In FY 2008, we continued to study holographic recording techniques, including multiplexing and wavefront compensation to compensate for distortion in recording media, and technologies for creating drives.

We are using an angular multiplexing in which the angle of the recording media is gradually changed by a fixed angle interval during recording. We noticed that the error rate could be reduced by varying the angle-change interval, so we developed a new technique for controlling the recording angle interval. We created prototype test recording and playback equipment combining a Fourier transform lens with a numerical aperture of 0.45, a phase conjugate optical system, and this new method (Figure). The new method enabled us to decrease the error rate even when we increased the multiplex number in 1-mm-thick recording media from 200 (as in the earlier media) to 300. The playback signal had practically low bit error rates of the order of  $10^{-4}$ .

A small amount of distortion occurs in photopolymer recording media during recording, and this causes signal degradation during play back. In FY 2007, we developed a wavefront-compensation technology that reduces distortion in a

white image caused by recording media distortion. In FY 2008, we compensated for degradation in 2-dimensional digital data and devised a technique for improving the playback-signal's characteristics. We used a genetic algorithm (an optimization technique modeled after the process of biological evolution) applicable to non-linear systems for controlling the wavefront compensation. With this algorithm, we were able to find new evaluation parameters corresponding to the 2-dimensional digital data and to use them to optimize the wavefront compensation. Accordingly, the playback data could be correctly obtained even when the recording media's distortion made it difficult to get an adequate playback signal. We also tried to increase the speed and accuracy of the wavefront compensation control.

As with optical disk equipment, positional control using a servo signal is necessary when recording and playing back data from holographic recording media. We attempted to obtain a servo signal directly from a periodic signal in the data. We devised a new technique for obtaining the servo signal from the frequency characteristics of the periodic signal. We confirmed that the periodic signal is a strongly correlated with the signal-to-noise ratio of the playback data signal and is useful as a servo signal. We have started to incorporate this technique in our holographic recording and playback test equipment.



# Research on useful and universal services

## OUTLINE

We are exploring ways in which technology can be adapted to users' demands and viewing environments by establishing links between diverse types of media, between broadcasters and viewers, and among viewers themselves. We are also researching and developing interfaces that are accessible to children and the elderly, supporting the formation of communities among viewers, handling data securely to provide reliable and trustworthy viewing platforms, and improving viewer satisfaction. We have been researching the potential services enable by these technologies, as well as conducting research geared towards useful and universal services.

### 2.1 Connecting broadcasting with media

The 12-GHz satellite broadcast band will be made available for digital broadcasting in 2011. With this in mind, we have been researching advanced satellite digital broadcast transmission schemes, IP packet multiplexing schemes, high-speed download services and new data broadcast techniques, and we have contributed to deliberations by the Association of Radio Industries and Businesses (ARIB) and the ITU Radiocommunication Sector (ITU-R).

We have verified the effectiveness of interference cancellation techniques for receivers and their compatibility with compensators for broadcast-wave relays. These techniques will smooth the transition from analog to all digital terrestrial television broadcasting, which is scheduled to be completed by July 24, 2011.

We continued to study on using part of the One-Seg terrestrial digital broadcasting band for the transmitting earthquake early warnings so they can be promptly displayed on receiver terminals, and we made a prototype alarm clock with an automatic warning function based on this idea.

We continued to investigate new forms of broadcasting for handheld terminals using from 1 to 3 VHF channels. As part of a consortium of 17 companies including commercial radio broadcasters, we proposed a scheme to the Telecommunications Council Broadcast Systems Committee that meets the goals laid out in their document "Technical Systems Relating to Multimedia Broadcasting for Handheld Terminals."

Regarding terrestrial broadcasting of Super Hi-Vision and other high-bandwidth next-generation services, we began researching and developing terrestrial digital broadcasting schemes that offer new benefits besides those of the current terrestrial digital broadcasting scheme (ISDB-T).

We also made progress in program delivery systems using an IP overlay network. Such systems promise efficient program delivery via the Internet by using receiver terminals as relays.

### 2.2 Connecting people with media

We are working towards implementation of AdapTV, a broadcast service that adapts broadcast content to the viewer's preferences, competence (age, disability, etc.) and viewing environment (display resolution, etc.). A Java data transmission platform is planned for this service, and so far, we have developed a system for receiving Java data broadcasts and a prototype application that runs on this system.

The advent of thin, lightweight, flexible high-quality displays will make it easy to view content anywhere and at any time. To this end, we are developing organic EL and film liquid crystal devices as well as organic thin-film transistors (TFTs) to drive them.

With regard to language processing technology to eliminate language barriers, we studied Japanese/English machine translation of severe weather alerts and developed a "translation palette" system to support the work of translators.

Moreover, we have been studying audio description broadcasting services and barrier-free information terminals that will enable visually impaired persons to access the diverse information provided by digital broadcasts.

We are studying new types of displays for ultra-realistic broadcast systems. In particular, we are seeking to develop displays that will convey multi-sensory information such as three-dimensional forms and tactile feedback revealing surface textures.

We are studying technologies to make it easier for the elderly to hear subtitles and narrations in the presence of background noise and for visually impaired persons to acquire auditory information.

We are looking in to how speech recognition technology can be used to extract metadata from programs automatically and how the extracted metadata can be used for searching content and improving closed-caption subtitles for the elderly and hearing impaired.

To implement a framework that makes it easy for anyone to utilize video resources, we developed technology for extracting data (metadata) describing video content and for utilizing content based on this metadata.

### 2.3 Connecting viewers with one other

We developed an Internet television system that makes it possible for ordinary users to create and post television programs as easily as blogs.

To increase opportunities for viewer interaction in the Internet era, we are researching and developing an intelligence circulation system that uses broadcast programs as a springboard for new network services, and we made progress on sentiment analysis technology for quickly analyzing the reactions of viewers to programs.

## 2.1.1 Advanced satellite digital broadcasting

Analog satellite broadcasts in Japan will end in 2011, and three channels will become available for new services. Moreover, another four new channels are to be added; these were allocated to Japan at the World Radiocommunication Conference 2000 (WRC-2000). These channels present an opportunity to offer digital broadcasting services with more appeal by exploiting rapid advances in telecommunications technology. With this in mind, we are researching advanced digital satellite broadcasting transmission schemes, IP-packet multiplexing schemes, high-speed download services, and new data transmission techniques, and we have contributed to deliberations at the ITU-R and the Association of Radio Industries and Businesses (ARIB).

### Transmission schemes

We had discussions at ARIB relating to advanced digital satellite broadcasting transmission schemes. The transmission scheme proposed by NHK employs LDPC coding and uses a reduced roll-off rate to maintain the same bandwidth occupancy and service time factor as existing digital satellite transmissions, while bringing benefits such as the ability to increase the transmission capacity from 52.17 Mbps to 70 Mbps. From November 2007 through May 2008, the ARIB digital satellite broadcasting enhancement working group performed verification trails using transmitter and receiver equipment made by NHK and confirmed that the functionality and performance of the transmission scheme meets the requirements. This scheme was adopted by the Telecommunications Council in reports relating to Inquiry No. 2023 (Technical Requirements for Broadcasting Systems). Our findings were reflected in the technical standards based on this report.<sup>(Note)</sup> At present, we are continuing with preparations of standards at ARIB.

### Development and standardization of IP-packet multiplexing scheme

We continued with the development of an IP-packet multiplexing scheme. This involves three techniques - header compression to reduce overheads by replacing the IP header information with a transmission header, transmission control signals that identify the broadcast wave signals in which the IP packets are multiplexed, and TLV packets to accommodate these headers and signals on the broadcast transmission path. In FY2008, we built a prototype transmission test system based on this IP-packet multiplexing scheme (Figure 1), and we confirmed that it was capable of transmitting IP packets with lower overheads.

The multiplexing scheme was also employed in parts of the above-mentioned report and reflected in the technical standard.<sup>(Note)</sup> We are continuing with the preparations of standards in ARIB's multiplexing working group. To reflect this multiplexing scheme in international standards, we



Figure 1. Advanced satellite digital broadcasting IP packet transmission test system

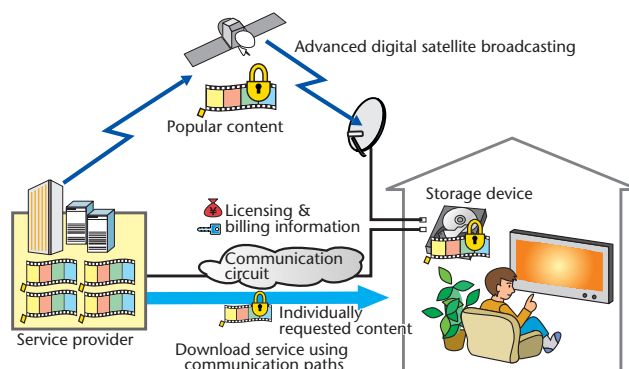


Figure 2. Broadcast download services in advanced digital satellite broadcasting

also submitting proposals to the ITU-R with a view to creating new recommendations for variable-length packet multiplexing.

### Broadcast download services

Since IP packet multiplexing schemes are suitable for transmitting non-real-time content, we are studying their use in broadcast download schemes for storage-type broadcast services.

By using download schemes, we can provide more viewers with a wider diversity of content by using telecommunications paths to deliver individually requested content and broadcast transmission paths to deliver popular content simultaneously to all parts of the country (Figure 2). In FY2008, we determined the requirements of download services and conducted a detailed study of the technical specifications.

We are working with the ARIB multiplexing working group's download scheme task group to draw up standards for this sort of technology.

### Creation of new data broadcast specifications

We studied Java-based data broadcasting schemes as possible extensions to ARIB-J (ARIB STD-B23), and we summarized the functional requirements of such schemes. Besides expanding the capabilities of closed-caption control data, we proposed additional functions for 1) expanding the user interface's capabilities with a mouse or the like, 2) providing compatibility with storage-type applications and with common-carrier applications that can operate on any channel, 3) starting up applications, using home networks, 4) acquiring TS (transport stream) packets and the like and outputting them to the network, and 5) linking up with BML so that ARIB-J can be called from the BML.

These functions make it possible to offer a wide range of services, including services that use the functions of equipment connected to home networks and broadcast services that present information suited to the viewer's preferences.

We will start trial Java data broadcasts in 2011 and submit proposals to ARIB-J regarding revisions to STD-B23 including these extended functions, and we are participating in the deliberations of the application execution engine task group.

(Notes)

Radio equipment regulations (1950 Radio monitoring committee regulations No. 18) Ministry of Internal Affairs and Communications 2003 directive No. 26, Ministry of Internal Affairs and Communications 2003 public notification No. 42 Ministry of Internal Affairs and Communications 2009 public notification No. 88

## 2.1.2 Fixed reception of terrestrial digital broadcasting

### Towards implementation of broadcast relay compensator

We have been constructing terrestrial digital broadcasting relay stations throughout Japan in advance of the scheduled termination of analog television broadcasts in 2011. To make effective use of broadcast frequencies and reduce the cost of relay station facilities, STRL has developed compensators against forms of various interference affecting signals received from upstream transmitter stations in broadcast relays. These compensators are inexpensive and do not require new frequencies on which to operate.

In FY2008, we conducted a 21-day field trial of multipath equalization equipment for broadcast-wave relay stations in cooperation with other NHK departments and a commercial broadcaster (Chukyo TV) (Figure 1). The equipment compensates for multipath interference between signals whose delay differences fall outside the guard interval (GI). The field trials were performed at the Mizunami relay station in Gifu prefecture, where multipath interference outside the GI is caused by reflections from ships in Ise bay. We also conducted similar field trials in cooperation with related departments at the Tokiminami relay station in Gifu prefecture, the proposed receiver site of the Inabu relay station in Aichi prefecture, and the relay station in Tosa-cho, Kochi prefecture. Favorable results were obtained in each case.

### Interference cancellation technology for domestic receivers

Co-channel interference from distant transmitters using the same frequencies can in some cases make it impossible to receive signals despite high field strengths. Receivers in poor reception environments need interference cancellers with a simple configuration. We investigated an adaptive array that uses a re-modulated time-domain signal including channel distortion as a reference signal (Figure 2). In computer simulations and outdoor tests, we confirmed that it is possible to suppress interference in poor reception environments. In terrestrial digital broadcasting, abnormal propagation of radio waves and

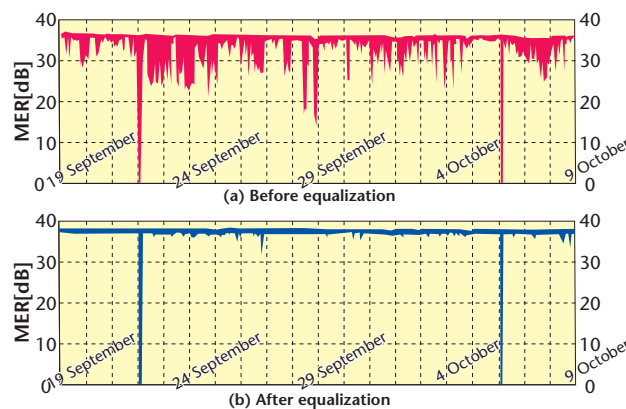


Figure 1. MER (modulation error ratio) before and after equalization

reflections from distant mountains can give rise to multipath interference outside the GI. To overcome such multipath distortion, we developed a technique that takes a fast Fourier transform over multi-symbol durations. In FY2008, we improved our equalization algorithm to make it more effective in poor reception environments and we built prototype performance-verification hardware.

### Next-generation terrestrial broadcast schemes

To accommodate the high bit rates of next-generation services such as Super Hi-Vision, we are researching new terrestrial digital broadcasting schemes that will be more capable than the current terrestrial digital broadcasting system (ISDB-T). Each carrier symbol (64 signal points) of the OFDM signal in ISDB-T transmits up to six bits of information (Figure 3(a)). In FY2008, to confirm the feasibility of ultra-high density OFDM transmission, we performed laboratory tests with an experimental modem that transmits up to ten bits per carrier symbol (1,024 signal points) (Figure 3(b)). To increase transmission capacity, we started to investigate a dual polarization diversity technique that uses horizontal and vertical polarization simultaneously, and we studied transmitter and receiver antennas and a modem for dual orthogonal polarized multiple access. We also began work on a new modulation technique to replace OFDM.

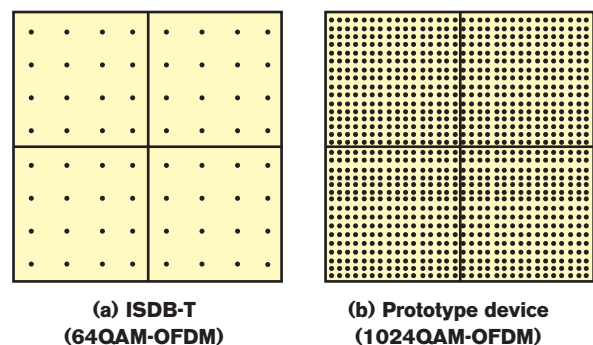


Figure 3. OFDM signal constellation

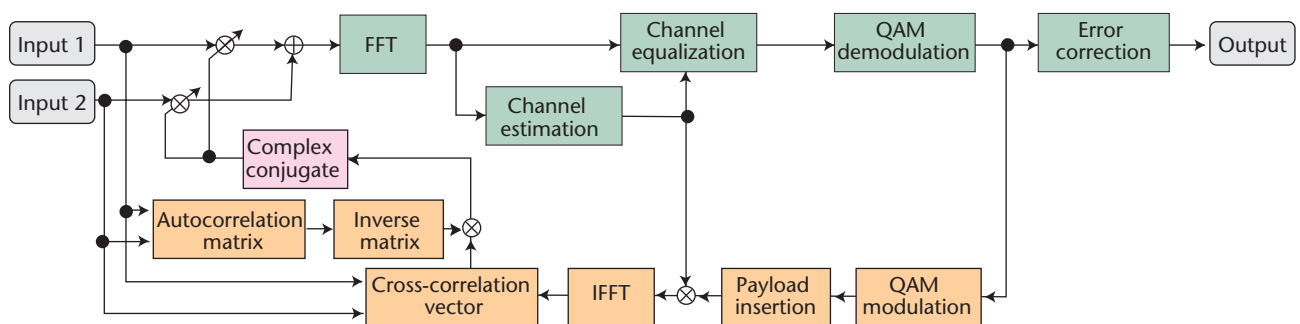


Figure 2. Functional block diagram of an interference cancellation technique for domestic receivers

## 2.1.3 Study on mobile/handheld reception for terrestrial digital broadcasting

### Automatic activation of receiver terminals by earthquake early warnings

Earthquake Early Warnings are advance warnings about the imminent arrival of strong tremors in places some distance from the epicenter. The scale of the earthquake and the position of its epicenter are estimated from data obtained by seismographs near the epicenter as soon as the earthquake occurs. The Japan Meteorological Agency issues an Earthquake Early Warnings whenever an earthquake with strong tremors with a seismic intensity approaching 5 or greater occurs anywhere in Japan. NHK automatically broadcasts these Earthquake Early Warnings in its programs, but so far there has been no way of automatically switching on receivers when this happens. We are studying techniques for transmitting Earthquake Early Warnings by using the Auxiliary Channel (AC) carriers of One-Seg terrestrial digital TV broadcast signals and displaying them promptly on receiver terminals. We have made a prototype alarm clock with an automatic warning function (Figure 1). In addition, we submitted a proposal for the One-Seg AC Earthquake Early Warning system to ARIB and worked on getting this system adopted as an official standard. We also worked on the circuit design of a One-Seg demodulation LSI that has an automatic activation function.

### Multimedia broadcasting for handheld terminals

We are studying new forms of broadcasting for handheld terminals using 1-3 channels in the VHF-Low band that will become available after the termination of analog TV broadcasting. In the document *Technical systems relating to multimedia broadcasting for handheld terminals* published by the broadcast systems committee of the Telecommunications Council, we, as part of a consortium of 17 organizations including radio broadcasters, proposed a broadcasting scheme that can be applied to the VHF-Low band. This scheme is based on the existing ISDB-T<sub>SB</sub> digital audio broadcasting standard, but includes various improvements such as the ability to transmit 30 frames of video per second like standard TV signals and a download capability. With regard to the parameters of multimedia (MM) broadcasting for handheld terminals, we conducted an investigation taking parameters such as current reception performance into consideration based on existing ISDB-T<sub>SB</sub> reports. Since this system uses VHF channels 1-3, we performed laboratory tests to examine the effects of interference with the FM broadcasts of neighboring providers. Regarding MM broadcasting interfering with FM broadcasts, we used 11 FM receivers to determine the protection ratio corresponding to the guard band. Regarding

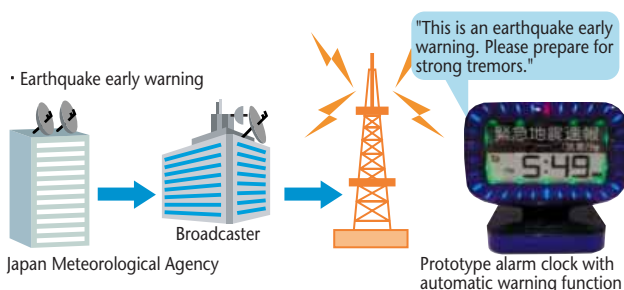


Figure 1. Automatic activation of receiver terminals by earthquake early warnings

FM broadcasts interfering with MM broadcasts, we obtained the protection ratio in experiments with a digital receiver prototype. These values were reported to the broadcast systems committee of the Telecommunications Council as planning parameters for MM broadcasting.

### Reception technique for high speed mobile reception

Following on from FY2007, we researched a technique that allows terrestrial digital HDTV broadcasts to be received stably even by equipment traveling at speeds in excess of 300 km/h. In FY2008, we confirmed the effectiveness of directional diversity reception by analyzing the results of mobile reception tests of an array antenna system combining space diversity reception with directional diversity reception. To make the equipment operate more stably with a multiple-maximum signal-to-noise ratio (M-MSN) adaptive array antenna, we simulated the effects of improvements to the algorithm and improved the prototype equipment by increasing the number of array elements from four to eight. In a joint study with KDDI, we investigated the key technologies of next-generation terrestrial digital broadcasting with improved mobile transmission characteristics and performed a computer simulation to evaluate the benefits of making ISDB-T more robust against multipath propagation by applying rotational OFDM (R-OFDM) (Figure 2).

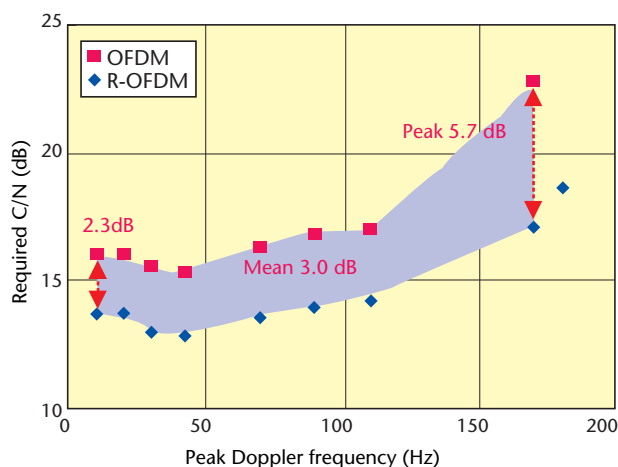


Figure 2. Improved reception performance through R-OFDM

### UHF-band folded type rectangular loop antenna

We developed a folded type rectangular loop antenna (FRLA) that for small handheld One-Seg terminals. In FY2008, we studied the use of multiple higher-order modes to increase the FRLA bandwidth. An ordinary loop antenna resonates at frequencies that are multiples of the basic mode (higher-order modes), but an FRLA can approximate the resonant frequency of each higher-order mode. To utilize these higher-order modes, we incorporated more folds on the long side of the FRLA than on the short side. This configuration leads to lower resonant frequencies in higher-order modes and a well-formed radiation pattern even in the higher-order modes. We confirmed by computer simulation that multiple higher-order modes can be accommodated within the frequency band of terrestrial digital broadcasts (470-770 MHz). The terminal's casing affects the antenna characteristics and causes the resonant frequency to change, so we also investigated this effect.

## 2.1.4 Next-generation video coding

We are researching next-generation video coding techniques in order to improve video coding schemes such as MPEG-2 and AVC/H.264. In FY2008, we developed algorithms to enhance the image quality of the coding schemes and developed codecs and video quality measurement equipment.

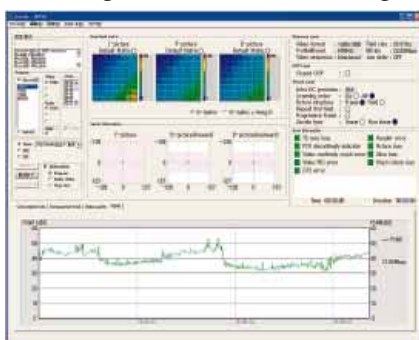
We worked on a coding scheme that uses a combination of DCT (discrete cosine transform) and DST (discrete sine transform). A new intra-image prediction algorithm delivered a 0.2 dB improvement in picture quality.

We developed a new post filter that reduces noise by applying wavelet shrinkage along the time and space axes of moving pictures. This filter is suited to wavelet coding techniques such as Dirac, which was developed by the BBC. By applying it to Super Hi-Vision video, we confirmed that it can effectively reduce noise especially in low brightness regions. In a joint study with Waseda University, we investigated a new technique for improving image quality by combining multiple coded and decoded images together, and we demonstrated that this technique is particularly beneficial when used in combination with motion compensation and multiple coding schemes. We also studied super-resolution images based on wavelet analysis and interpolation by spatial directional correlation. This technique uses a

maximum likelihood distribution estimate of pixel correlations in the spatial directions and generates unknown pixel values by using interpolation based on a two-dimensional Lanczos function.

For purposes such as gathering news contributions, we developed a compact high-resolution video codec based on JPEG2000 compression. This codec can encode video at up to half the screen size of Super Hi-Vision and can record and play back video using a single-channel HD-SDI recorder. Since it performs encoding in field time units, it has low latency and can easily be used for the transmission and editing of high-resolution video.

We also developed novel video-quality measuring equipment that objectively measures the degradation of MPEG-2 coding schemes used in digital broadcasting (Figure).



Video quality measurement equipment

The method estimates the PSNR (peak signal-to-noise ratio) by utilizing the time variation of the energy of alternating frequency components in each decoded video frame. In PSNR estimation tests, we confirmed that there is a very strong correlation with a contribution ratio of at least 0.95 between the measured values and estimated values. By speeding up the algorithm, we were able to implement this technique with a commercial PC.

## 2.1.5 IP broadcast systems

We have been researching IP (Internet Protocol) broadcast systems that exploit the benefits of IP communication for broadcasting applications, especially its ability to use diverse wired and wireless transmission paths.

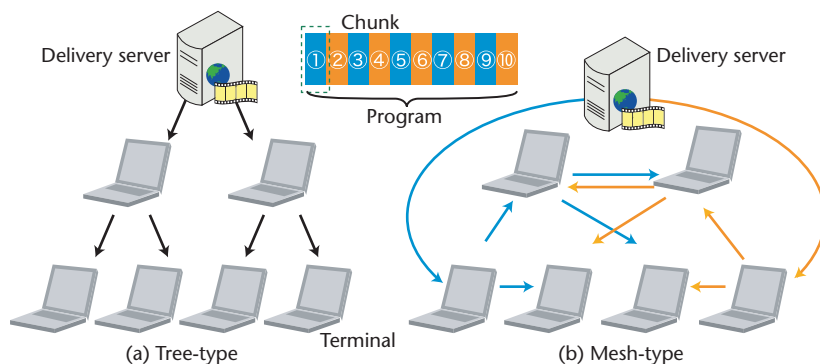
In FY2008, we studied a program delivery system that uses an overlay network to deliver programs efficiently over the Internet by using receiving terminals as relays.

We compared the delivery efficiency and stability of two delivery modes - a tree-type delivery mode where terminals are used as relays and program data is delivered in sequence from the server (Figure), and a mesh-type delivery mode where the program data is finely subdivided and is sourced from nearby terminals forming a network. The tree-type delivery mode is expected to have greater delivery

efficiency, but if a relaying terminal stops working in the middle of a program then all the downstream terminals are affected. Using prototype equipment, we evaluated the delivery efficiency and the effect of terminal disconnection in the mesh-type delivery mode, and we confirmed that this mode is capable of highly efficient and stable delivery.

We conducted Super Hi-Vision (SHV) transmission tests on the international IP network to study a high-quality and reliable transmission system based on IP technology.

In general, it is difficult to transmit IP packets without any losses on an IP network. We therefore used error-correction techniques to transmit signals requiring high quality. We examined the trade-off between protective effects and the increase in bandwidth throughout the preliminary transmission experiments, and based on our findings, we established practical error-correction parameters for the transmission of SHV signals. We also configured a redundant network with an automatic fail-over system and a remote monitoring system to ensure reliability. As a result, we were able to conduct the world's first demonstration of SHV transmitted on an international IP network between the UK and Holland at IBC2008, and we reliably transmitted high-quality live SHV.



Program delivery modes using receiving terminals as relays

## 2.1.6 Broadcast security

We are promoting the seamless use of broadcasting and telecommunications and the beneficial utilization of digital content in advanced applications, and we are researching security techniques that protect user privacy and content while still allowing users to access content in a convenient way.

### Downloadable CAS technology

We studied a conditional access system (CAS) for advanced digital satellite broadcasting. To provide content rights protection and access control functions for ultrahigh-definition video, we will have to develop an advanced form of CAS technology with stronger security than that of the current digital broadcasting. We clarified the requirements of such a CAS for advanced digital satellite broadcasting and developed a downloadable CAS that enables updating of program codes with security functions (Figure 1).



Figure 1. Prototype receiver with downloadable CAS

### Multi-device single sign on

Users would like to continue using the same service when they switch between mobile handheld devices and stationary television sets. To enable seamless switchover, we developed a way for devices belonging to the same user to share authentication information. This new technique eliminates the need for repeated authentication operations for each device and lets users migrate services seamlessly from one device to another without having to stop and search for the place where they left off.

This technique has been adopted as a use case in the Liberty Alliance\* web service framework (ID-WSF).

[Joint study with NTT]

\* A nonprofit organization that was set up to develop an open specification for identity federation in network services. Members include over 150 corporations, groups, and governments from around the world.

### Data broadcast technology that can generate individual QR Codes

We cooperated with the engineering administration department in developing BML (Broadcast Markup Language) coding technology to generate QR Codes containing receiver information such as a B-CAS card ID or user variables with limited receiver resources. By scanning QR Codes with a camera phone, a user can access a server and perform authentication with a B-CAS card ID instead of having to enter a long ID (Figure 2).

### Authentication control techniques for hand-overs between disparate networks

We studied a hand-over authentication control scheme



Figure 2. Data broadcast technique capable of generating QR Codes

that can provide seamless content delivery services between different networks and handheld devices based on Mobile IPv6 and Proxy Mobile IPv6. This scheme speeds up the hand-over process by making the authentication processes for networks, devices, and services more efficient. It does so by splitting the encryption key and transmitting it across each of the paths over which data is passed during the hand-over. At the device end, the encryption key is regenerated so the content can be correctly decoded.

[Joint study with KDDI R&D Laboratories]

### P2P content delivery/management systems

We devised a scheme for users to view broadcast content delivered via P2P networks. The scheme employs a combination of push-type delivery based on receiver control information and program delivery information used in digital broadcasts.

For supplementing broadcast content download services (see section 2.1.1), we developed a scheme that reduces the update processing time by issuing summarized update requests of the content list in the distribution hash table (DHT) to the receiving terminals on the path to the content location management terminal. Each receiving terminal equipped with P2P delivery functions has its own DHT. This technique can be used to implement systems with distributed access to the management terminal even if content is downloaded to many terminals at the same time.

### Group signatures and public-key encryption

We developed user authentication and public-key encryption schemes for bidirectional broadcasting services. To preserve user privacy when accessing services, we developed a group signature scheme that makes it easy for users to leave a group. We theoretically demonstrated that this scheme has a lower computational cost and uses smaller signatures than conventional group signatures, and we proved that it is efficient.

In terms of public-key encryption, we developed a scheme that is secure and whose security proof is easy to understand.

### Digital watermarks that persist in re-shot images

We researched a technique for making digital watermarks that can still be detected in images displayed on a television or movie screen and recaptured with a video camera. We improved the embedding algorithm and increased the detection rate. We also evaluated the technique's ability to withstand various compression techniques.

[Joint study with Mitsubishi Electric Corporation]

## 2.2.1 Flexible displays

STRL is researching organic electroluminescent (EL) and liquid crystal film devices, as well as organic thin-film transistors (TFTs) to drive these devices. Our aim is to develop thin, lightweight, flexible displays so that television program content can be enjoyed anytime, anywhere.

### Organic electroluminescent devices

To improve the luminous efficiency and lifetime of organic electroluminescent devices that use phosphorescent materials, we optimized the host material (the main constituent of the emission layer) and device structure. In FY2008, we achieved a luminous efficiency of 13% for green light and a fourfold increase in lifetime by using a novel host material with a spiro structure. We also demonstrated that this material can be used in solution processes and that an efficiency of 10.5% can be achieved in devices fabricated by spin-coating. We also obtained an efficiency of 12% in white-light emission devices having a double emission layer. We measured the electroluminescent decay characteristics when these devices were driven with ultra-short pulses, and it appears that efficiency is increased by the light emission region becoming thicker due to energy transfer from the blue to the green and red phosphorescence guest molecules added to the host material.

### Liquid crystal film devices

Our goal is to increase the size of flexible television displays, and we studied liquid crystal film display devices in which a composite film of fast-response (ferroelectric) liquid crystals and fine polymer structures (synthetic resin) stabilizes the gap between the two plastic substrates. In FY2008, we built a prototype flexible liquid crystal film display panel (5.1inch diagonal, 128×172 pixels) by directly forming polycrystalline silicon thin-film transistors with high charge mobility on a plastic substrate at low temperature ( $\leq 150^\circ\text{C}$ ) and by using printing and coating processes to form a liquid crystal/polymer composite film and alignment /insulator layers. We also developed a flexible backlight based on a transparent silicon rubber light guide plate and edge lighting with small LED chips in the three primary colors (the LED-supporting parts are also flexible). We then fabricated a full-color video display (Figure 1) by using fast-response liquid crystals and high-speed TFTs to perform field-sequential color driving. By dispersing a polymer in the memory-type liquid crystal material (cholesteric liquid crystal) for reflective displays, we made new flexible liquid crystal devices with reflection wavelengths that exhibit excellent stability against changes in ambient temperature.

### Organic TFT materials

We are researching organic semiconductor materials and TFT structures for enhancing the performance of organic TFTs. In FY2008, we investigated the environmental stability of five types of organic semiconductors in order to clarify the factors that dominate this property. We found that contact with oxygen causes a

threshold shift in organic semiconductors with a highest occupied molecular orbital (HOMO) of less than 5.2eV and that the off current increases as the HOMO level decreases. We also studied how oxygen affects the field-effect mobility and found that field-effect mobility is not an interface issue but depends on the chemical stability of the organic semiconductor itself. We are also researching organic TFTs based on liquid crystalline semiconducting polymers that can be formed into thin films in a solution process. X-ray diffraction patterns revealed that the thin-film morphology of the liquid crystalline semiconducting polymer could be changed from a disordered one to a well-ordered one by annealing at from  $130^\circ\text{C}$  to  $170^\circ\text{C}$ . We also made a prototype organic TFT with a fluorine-based polymer gate insulator and a semiconducting polymer layer, both formed by spin-coating, and we obtained a field-effect mobility of  $0.14\text{ cm}^2/\text{Vs}$ , which is sufficient for driving organic electroluminescent devices.

### Flexible display driven by organic TFTs

We require active matrix driving circuits based on flexible organic TFTs in order to create a flexible video display with high brightness, high contrast and a long lifetime. The organic TFT has a gate insulator made of  $\text{Ta}_2\text{O}_5$ , which is fabricated with an anodic oxidation method. The gate insulator can be fabricated at room temperature and the device is capable of low-voltage operation. In FY2008, by reducing the pixel pitch and increasing the pixel count of the TFT arrays, we succeeded in forming a TFT array with a pitch of 42ppi on a plastic substrate. The TFTs used pentacene in the organic semiconductor layer. They operated at a low voltage of 5V and had a mobility of  $0.1\text{ cm}^2/\text{Vs}$  and a current on/off ratio of  $10^5\text{-}10^6$ .

We made a prototype array for an organic EL panel with two TFTs per pixel by patterning organic semiconductor with a double passivation layer (poly-para-xylene +  $\text{SiO}_2$ ) and photolithography. On this TFT array, we formed a  $213\text{ (RGB)}\times 120$  pixel color panel with a diagonal dimension of 5.8 inches by using vacuum deposition and inkjet printing to form phosphorescent organic electroluminescent devices that efficiently emitted light. We confirmed that this panel could display color video images at a frame rate of 60 Hz and operate when it was bent into a curved shape (brightness  $30\text{cd}/\text{m}^2$ , Figure 2).

We worked on optimizing the channel width/channel length and storage capacitance of liquid crystal film panels, and we were able to display color video images at a frame rate of 60Hz by using field sequential color driving on a  $160\times 120$  pixel panel with a diagonal dimension of 5 inches driven with a write speed approximately six times the monochrome display speed (Figure 3).



Figure 1. Liquid crystal film display driven by polycrystalline silicon TFTs (128×72 pixels)



Figure 2. Flexible organic EL display driven by organic TFTs (213×120 pixels)

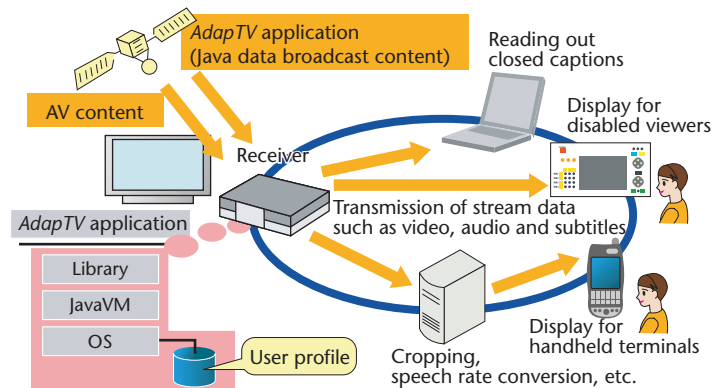


Figure 3. Liquid crystal film display driven by organic TFTs (160×120 pixels)

## 2.2.2 AdapTV: A service that adapts to the viewing environment

We have been conducting research and development aimed at the realization of *AdapTV*, a broadcast service that adapts the broadcast content to the viewers' circumstances and preferences. It does this by converting the received broadcast content to suit the viewing environment and viewer-related attributes, such as the resolution of the viewing terminal or the viewer's program preferences. In FY2008, as a base technology to build a receiver environment for *AdapTV* services, we worked on a prototype Java data broadcast receiver system and applications that will run on this system.

Regarding Java data broadcast receivers, we enhanced the user interface to include a free-moving cursor, enabled



Concept of implementation of *AdapTV* using Java data broadcasts

forwarding of the entire broadcast stream or parts thereof (e.g. closed caption data) to other equipment connected to a home network, and developed Java data broadcasting acquire the broadcast stream content. We implemented these functions in the receiver and verified their functions. We also verified the feasibility of building *AdapTV* services using Java data broadcasting by

applications with a cropping device and a text-to-speech device on a home network. These applications show *AdapTV* services can be built upon Java data broadcasting.

In addition to the above-mentioned receiver, We also created an application development platform emulator. The emulator provides greater computing power for intelligent applications. However, considering the limited computational power of digital TV sets, it is also necessary to reduce the processing load. We analyzed the internal processing of the applications toward new additional libraries with a practical processing load.

We sent researchers to the British Broadcasting Corporation's (BBC) research laboratories, and we began studying services that use communications networks for transmitting closed caption data to remote servers over the Internet for use in personalizing broadcast programs.

## 2.2.3 Language processing for the elimination of language barriers

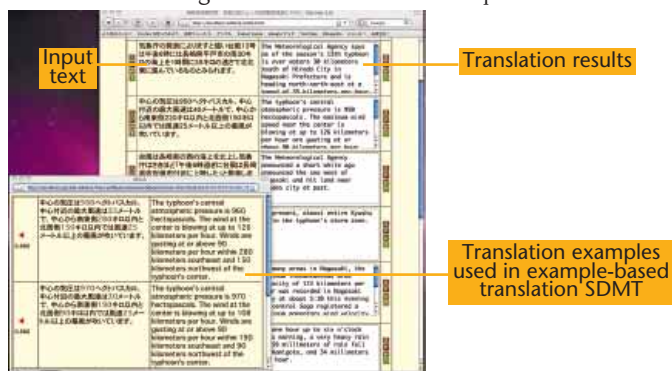
### Japanese-to-English translation of severe weather warnings

We have been researching a machine translation system based on our example-based translation scheme called SDMT (Similarity-Driven Machine Translation). This system performs translations by using a translation example database consisting of Japanese sentences and their English counterparts. Specifically, the system searches the translation example database for a set of Japanese sentences whose similarity to the input Japanese text exceeds some threshold value and generates a translation by combining the corresponding English sentences. Since example-based translation is particularly effective for translations that are confined to a particular field, we have been researching the use of this technique for severe

weather warning bulletins. In FY2008, we developed a simplified version of the group of modules required for translation and a GUI that can reference the translation examples used during machine translation. We also created an experimental prototype (Figure: GUI of example-based translation SDMT). Furthermore, we investigated methods for producing translations with priority given to the translation of proper nouns and number expressions.

### Simple Japanese

We have started researching how to rephrase news text to make it easier to understand for foreigners with a basic level of Japanese ability. In FY2008, we interviewed specialists in Japanese language education to get a general idea of the Japanese language ability of foreigners who have studied the basics of the language. Based on the experts' responses, we opted for a target Japanese language level corresponding to roughly level 3 on the Japanese Language Proficiency Test (where level 4 is the lowest level and level 1 is the highest level). Of the wide variety of factors that affect the difficulty of news texts, we focused our attention on three in particular: character type (kanji and hiragana), vocabulary, and syntax. In FY2008, we performed preliminary trials in which we measured the difficulty of news items by preparing a dictionary of kanji and vocabulary words of each level of the Japanese Language Proficiency Test. As a result, we found that there is a large difference between the difficulty of community and weather news genres.



GUI of example-based translation SDMT

## 2.2.4 Presenting information in a user-friendly way

We are studying ways of enhancing audio description broadcast services and barrier-free information technology in order to provide an environment where visually impaired persons can gather diverse information from digital broadcast services. We are also researching multi-modal presentation methods for conveying information such as tactile 3D shapes and surface textures together with content expressed in the form of figures and graphs. Ultimately, we hope to use these techniques to implement a universal realistic broadcast system.

### Presentation techniques for barrier-free information technology

The barrier-free information presentation system that we had developed up to FY2007 includes functions for converting content into an accessible form by constructing a tree structure and adding explanatory metadata. A characteristic of this presentation system is that it can display information in various different ways depending on the type and degree of visual impairment.

In FY2008, we developed a Braille interface that can be used to integrate web browsers with various Braille displays. By improving the vibration presentation functions to support content searches and adding functions that enable users to specify key assignments, we made it possible for this interface to be used with ordinary applications. To improve the usability of digital broadcasts, we also investigated a scheme for presenting television operations in the form of tree structures. We will incorporate the results of these preliminary studies in a practical presentation system.

Regarding the interactive tactile display we developed in FY2007, we made improvements to the finger pointing interface and we verified the algorithm used to present text information in Braille in real time. Regarding the presentation of tables and site maps, we conducted psychological experiments to ascertain how searches are affected by the number of objects presented in the display area by varying the size, separation, and layout of the objects. From an analysis of variance, we found that all these factors have a significant main effect, and we derived conditions on the number of objects and layout patterns that minimize the search time.

We also made a prototype experimental system that has fast display operations, and we used it to clarify the effects when the attributes of GUI objects are conveyed to multiple senses such as sound and touch (vibration) and the tactile recognition characteristics when video movement information is also transmitted.

### Research of multi-modal presentation methods

Using the prototype multi-finger virtual haptic display equipment that we built in FY2007, we conducted experiments in which virtual 3D models were presented in an environment with no visual information in order to clarify how the recognition of shapes is affected by the number of fingers that touch the object. In tests conducted



Figure 1. Virtual object presentation test using multiple fingers on both hands

with one finger and with multiple fingers (two fingers on one hand, four fingers on both hands), we found that the number of fingers with which the shape can be easily ascertained varies between subjects. This suggests that different people have different recognition mechanisms. We also discovered an illusion phenomenon whereby objects feel smaller when you touch them with more fingers.

### Audio description data broadcasting services for visually impaired persons

We continued with our research from FY 2007 into broadcast services for visually impaired persons. In particular, we studied services in which the broadcasting station automatically convert news flashes about earthquakes and tsunamis into audio files with a high-quality synthesized voice and transmits these files as a data broadcast to digital television receivers. In FY2008, we developed a technology that can transmit larger files containing more speech within a limited data broadcast bandwidth, and we used our prototype system to confirm its effectiveness. The compression rate of the audio files is smaller than the transmission bandwidth, so it is possible to transmit these files in several parts without restricting other data broadcast content. We confirmed that the receiver could reassemble these parts and play back the synthetic speech. Furthermore, by using up spare transmission bandwidth to transmit the same audio file more than once, users will miss fewer parts of a news flash even if they have just tuned in to the channel or turned on the receiver after the news flash has started. We also confirmed that our technology can deal with changes in the receiving conditions.

We conducted subjective evaluation experiments to determine guidelines for making more effective audio description broadcasts. Audio descriptions are inserted into silent sections of program audio, but in some cases, the insertion timing may shift, causing the two sound sources to overlap. Since there has been no quantitative evaluation of the difficulty in understanding audio descriptions that have been delayed and overlap with the start of the program audio, we conducted subjective evaluation experiments and found that the detectable overlap of the two audio sources is 0.15 seconds and the acceptable overlap is 0.48 seconds (Figure 2). Furthermore, we thought that the program audio and program description audio signals might be easier to distinguish if the two overlapping sounds were presented on separate speakers at different positions (Figure 2).

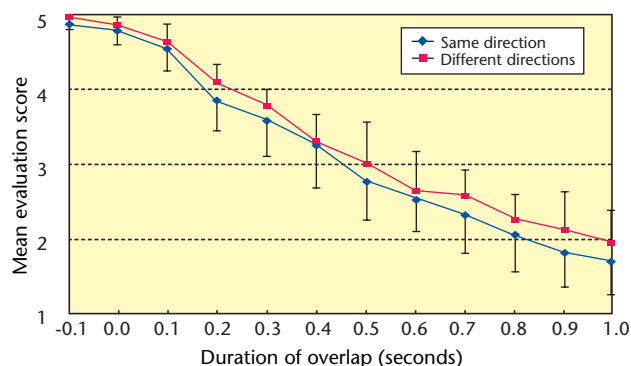


Figure 2. Results of subjective evaluation experiments on the amount of overlap between the program audio and audio description

## 2.2.5 Speech and audio signal processing for the elderly and disabled

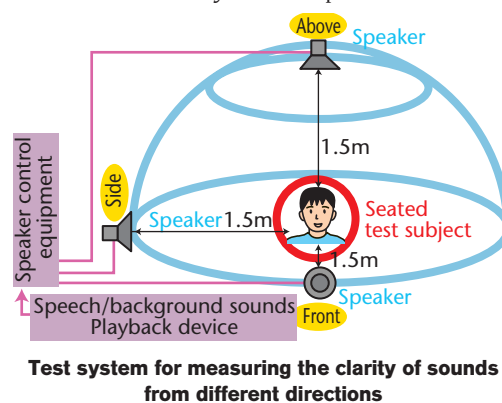
We studied acoustic reproduction technology that makes it easier for the elderly to hear spoken dialog and narration affected by background sound and technology to help visually impaired persons gather information.

Regarding acoustic reproduction technology for the elderly, by working together with broadcasters, we have already developed a device that calculates the (perceived) loudness of narration audio and background sounds and uses the difference between the two to obtain a subjective representation of how easy it is to hear the narration. In FY2008, we studied how to model the hearing ability of elderly persons more accurately.

First, we measured the phenomenon whereby small sounds become harder to hear (a common trait in elderly persons) over a range of different frequencies, and we implemented these measured characteristics in the device. We also conducted listening evaluation tests on Japanese monosyllables (50 syllables) presented together with noise. When the SN ratio was smaller than 12 dB, we found that the background noise made speech perceptually quieter, so we incorporated this effect into the device. We also added a function for outputting the program audio

processed to simulate sounds as heard by an elderly listener.

Regarding future acoustic reproduction schemes, we attempted to make speech in a program easier to hear by having the speech and background sound come from different directions. We performed speech comprehension tests on one group of test subjects in their 60s and 70s and another group in their 20s. The subjects were presented with speech (monosyllables and words) and background sound (noise, music) from speakers placed in different (and the same) directions (Figure). We found that the older test subjects had more difficulty comprehending the speech when the speech and music came from the same direction, but they found it easier to understand the speech when the background sounds and speech came from different directions.



Regarding speech rate conversion techniques, we studied a technique for supporting information acquisition for visually impaired persons that keeps speech content understandable when it is played back at 2-3 times the original speed, and we investigated a technique for playing back foreign-language broadcasts more slowly for elderly people in foreign countries. These studies were conducted jointly with NHK Engineering Services.

## 2.2.6 Speech recognition

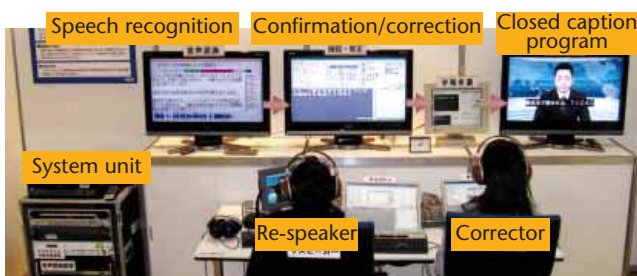
Our research on speech recognition has the aims of improving closed captions for hearing-impaired and elderly viewers and efficiently extracting metadata for purposes such as content searching. In FY2008, we improved the word accuracy for spontaneous speech in news and information programs and worked on a live closed-captioning system that can be operated by a few people. We also developed an automatic transcribing system for program audio that is useful for extracting metadata.

Spontaneous speech refers to speech that is uttered relatively freely within the scope of a specific subject, as opposed to read speech from prepared text such as news stories. In news and information programs such as *Today's Close-Up*, the parts where a presenter chats with his or her guest consist of spontaneous speech. Speech recognition does not perform as well on this type of speech because it tends to be faster and less distinct, and it contains

phraseology that is characteristic of spontaneous speech. We therefore studied a language model learning method that uses the frequencies with which words appear in the spontaneous speech of information programs and the recognition error correction results and a method for adapting acoustic models to the distinctive acoustic characteristics of spontaneous speech. As a result, we achieved a word accuracy of 82.3% for *Today's Close-Up* by eliminating over 20% of the recognition errors from the conversation sections selected for evaluation.

Regarding our new live closed-captioning system (Figure), which switches between direct recognition of the program audio and a "re-speak" recognition method (where recognition is performed on rephrased utterances by a different speaker) depending on the program content, we made it possible to update to the latest language model at any time, even while captioning is still in progress. We also added speaker recognition functions, studied how recognition performance varies with the type of news programs, and conducted trials in broadcast stations.

We developed an automatic transcribing system that applies real-time speech recognition to all the news programs that are broadcast every day, so that the recognition results can be archived along with the programs themselves. Besides its utility for speech recognition training, the archived data has a wide range of applications, including metadata extraction and content searches.



## 2.2.7 Intelligent content utilization

To make it easy for anyone to use video resources, we are researching and developing technology to extract data describing the content of video (metadata) and to enable the metadata to be utilized with the content

### Metadata production framework

For our second version of the Metadata Production Framework (MPF) (Our platform for metadata production technology), we drew up specifications for constructing metadata production environments over a network, and we set up a metadata server, metadata editor and metadata extraction module based on these specifications on the NHK STRL website. We also participated in the Information Grand Voyage Project of the Ministry of Economy, Trade and Industry. We made it possible to operate content analysis algorithms as metadata extraction modules based on the MPF specifications, and we developed a system for

searching metadata in MPF format. We also participated in a project run by the European Broadcasting Union (EBU) to investigate the feasibility of a metadata editor as an evaluation platform.



Figure 1. Screenshot of metadata editor (version 2.0)

### Content analysis techniques

Our studies in this area included using language processing to do content analysis of TV program structure, using image recognition to identify people depicted in video, and analyses of sports video content.

We conducted experiments in which we used linguistic analysis of closed-caption content to analyze the structure of "regular" programs with a relatively fixed format. Our goal is to develop ways of splitting programs into meaningful units automatically.

To identify people depicted in video, we embedded functions for detecting faces and we worked with the Broadcast Engineering Department to produce a video correction support system capable of correcting source video with degraded brightness balance by focusing on facial regions. This system was used in a broadcast production environment. To speed up the task of face detection, we developed a method that uses the bias in where faces appear in broadcast video (a statistical quantity representing characteristics such as a high frequency of appearance in the center of the picture) as a prior information. To register facial images of new characters from multiple angles, we developed a face recognition technique using a three-dimensional head model to automatically generate facial images with predetermined orientations from facial images taken from a small number of directions. We also developed techniques for classifying scenes based on visual objects, including a technique for detecting specific actions and a technique for detecting and

condensing redundant scenes. We also participated in the TRECVID international program of video retrieval evaluation trials.

In our research on sports video analysis, we increased the event detection accuracy by developing a technique for detecting events such as inning changes in a baseball match. We also developed a technique for integrating player tracking and player recognition in soccer matches and demonstrated the feasibility of tracking specific players. Our ball trajectory display system has been used to display pitching trajectories in live professional baseball broadcasts for five years, and it has also been used to show ball trajectories in live bowling broadcasts.

### Information searching techniques for television viewing

We have begun researching searching and browsing using metadata as a means of naturally expanding the usual television viewing experience and have devised *CurioView*, a new TV viewing style based on information retrieval. At the NHK Open House, we presented a prototype system using information extracted by content analysis. The system automatically searches for and displays programs, scenes, and information related to the video currently being viewed.

We investigated a search technique for *CurioView* that uses text data such as closed captions and Electronic Program Guide (EPG) information. We developed a framework for efficiently calculating the relevancy of texts to each other by comparing their feature vectors. By applying this technique to program descriptions and news articles, we confirmed that it is possible to perform searches for related programs that include more detailed descriptions than is conveyed in news headlines. We also developed a technique for extracting information about the relationships between visual objects from closed caption texts, and we implemented a scene search function that looks for the relationships illustrated in the program, e.g., a nature program showing predation of one animal by another. We also developed a framework for automatically adding semantic tags to closed caption text data by referencing an ontology that records the relationships between concepts, and we used this framework in a method for searching program-related content in various ways.



Figure 2. CurioView screenshot

### Content presentation techniques

We investigated a display method that makes it easy to ascertain the content of programs. We developed a technique for extracting highlight scenes suitable for introducing nature programs. This technique automatically detects visual objects such as the animals appearing in the program.

For items presented in news programs, we developed a technique for selecting text and images that appear to be representative of the item, and we performed tests in which multiple related news items were presented in an easily browsable form.

### 2.3.1 Omni resource type media

We are developing an Internet television system that enables anyone to produce and post television programs as easily as blogging.

The TV4U ("TV for you") service enables anyone to produce their own programs simply by writing a script. In FY2008, we began researching a more functional type of media (omni resource) that can handle live resources and joint productions.

We enhanced the program viewing, automatic program production engine, and video generation modules of TV4U.

For the program-viewing (TV Browser) module, we developed a function to allow TV4U programs to be presented on the Internet in the same style as on regular TV, and we demonstrated this function at the FY2008 Open House.

For the automatic program production engine (APE) module, we improved its modularity and reusability.



Figure 1. Shakiin (ETV)



Figure 2. Himitsu no Chikarando (ETV)



Figure 3. Tokusen (ETV)

Specifically, we used the object-oriented language Python to make a function for creating and modifying content. This makes it possible for users to share and modify parts of each other's productions.

For the video generation (TVML player) module, we developed a new TVML player with many new functions, including high-quality CG actors with detailed skeletal structures capable of making smooth movements of small details such as the fingertips, an external video input function, multiple language capabilities, and player state acquisition functions. We also strengthened the links with existing CG software and motion capture systems to enable the CG actors to make high-quality movements.

The ad-lib system we developed in FY2007 has been in constant use in the programs *Shakiin* (Figure 1) and *Himitsu no Chikarando* (Figure 2), and the new TVML player developed in FY2008 has been used on the program *Tokusen*

(Figure 3). We also released a freeware version of the script production tool TV Creator, which is simple, yet highly functional.

### 2.3.2 Support for viewer communities

The Internet generation tends to use computers more than television as a source of information and entertainment. Establishing strong links between viewers and broadcasters and personal links among viewers seems to be the key to keeping these people in contact with broadcasting. We have been researching techniques that analyze viewers' opinions about broadcast programs and provide swift feedback to program producers. We have also been studying an "intelligence circulation system" to share viewers' feelings about TV programs through the Internet.

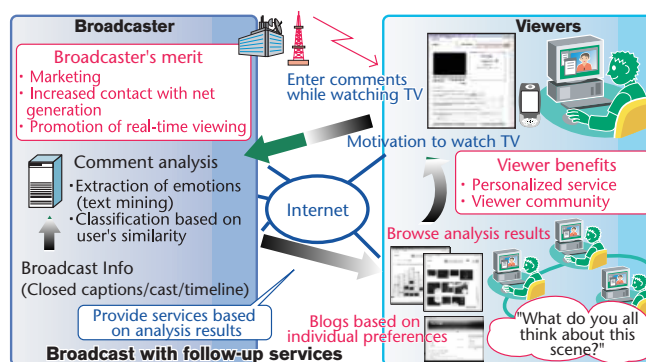
#### Opinion analysis techniques

Automatic analysis of opinions about broadcast programs consists of two parts - categorization of opinions into predefined types and identification of phrases that refer to the program. In FY2008, we constructed an automatic opinion categorization system that categorizes opinions into six types: (i) positive opinions, (ii) negative opinions, (iii) what the viewers learned from the program, (iv) what the program led them to think, (v) questions about the program, and (vi) requests related to the program. These types reflect the ones used in actual program production. In FY2007, we used machine learning to categorize opinions automatically, and in FY2008, we devised a technique that uses the linguistic features of predicates in the opinions. We also investigated a method for extracting phrases in opinions that refer to the program based on the phrase frequency among programs. We designed an opinion analysis system

that incorporates these techniques, and we are now building a prototype.

#### Intelligence circulation system

We are developing an "intelligence circulation system" which collects and analyzes viewer's comments about TV programs and creates feedback. In FY2008, we proposed an algorithm for inferring subjects and an algorithm for classifying comments into emotion groups. In addition, we proposed a service that visualizes classifications of viewers derived from the similarity of their comments and sends them back to the viewers. We implemented these analysis and visualization techniques in a prototype system and demonstrated that its operation is very quick.



Concept of intelligence circulation system

# Research on advanced content production environments

## OUTLINE

We are researching advanced production technology for creating appealing, high-quality content and technology for ensuring viewer's safety and security by promptly providing them with urgent information wherever they are. We are also analyzing aspects that attract viewers to excellent programming and assessing how knowledge of these aspects can be used to create new content.

### 3.1 Distributed production network

We are conducting research on a distributed broadcasting-station system that automatically combines production resources connected via a computer network so that editors can build their own editing studios wherever they may be.

To improve the characteristics of long-distance relay transmissions over optical fiber, we are incorporating pre-compensation methods in the optical transmitter that use a lookup table describing chromatic dispersion and non-linear distortion occurring along the fiber-optic transmission path.

### 3.2 Next-generation content-production systems

We are researching imaging technologies for viewing depicted objects from various directions, with the goal of applying them to video production and three-dimensional television.

There is increasing demand for high-quality composited video for dramas and other productions, so we have begun research on video compositing technology to raise the quality level from the input stage through to the processing stage and increase the efficiency of studio productions.

We improved the usability of mobile robot cameras for studio use and are developing outdoor robotic cameras that will be able to follow their subjects automatically. We also studied high-quality speech synthesis technology that automatically converts a manuscript into speech for normal broadcasts or reads out broadcast text (such as earthquake warnings) for visually impaired viewers. We are researching a single-panel organic color optical sensor device that alternates layers of organic photoconversion material for each of the three primary colors and transparent circuits for picking up the electrical loads of photoconversion layers. The device will lead to major size reductions for color cameras. So far, we have created prototype devices sensitive to two of the three colors, and we have verified that they can be used for color photography.

We also continued with our development of a HARP field-emitter array image sensor for use in compact, high-sensitivity Hi-Vision cameras that can be easily deployed to

cover night-time emergencies.

We doubled the frame rate of our ultra-high-speed camera that can take images of phenomena too quick to be seen by the naked eye, and this has enabled us to shoot various new phenomena.

We have begun work to eliminate the need for an external bias power supply for our silicon microphones.

We also are studying faster magnetic tape playback and faster, higher capacity optical disks for efficient and stable archiving of huge volumes of content.

To realize compact magnetic disks capable of recording uncompressed Hi-Vision signals, we are continuing with our research on perpendicular magnetic disks and recording heads.

Our research on estimating viewers' psychological state has the goal of objectively analyzing the psychological effects of programs on viewers. In particular, we have been studying the relationship between attention to the screen and brain activity. We have developed equipment that efficiently measures the gazes of several viewers at the same time.

### 3.3 Mobile reporting system

Our work on millimeter-wave mobile cameras has the goal of creating a wireless Hi-Vision camera for studio use. Our latest camera of this type was used on the NHK's annual New Year's Eve Song Festival.

Considering improvements in efficiency and reliability of 800 MHz-band field pick-up units (FPUs), as well as the results of outdoor multi-input/multi-output (MIMO) transmission tests, we studied technology for improving transmission characteristics in line-of-site situations. Moreover, we continued our research on a millimeter-wave TV camera that can shoot images of objects obscured by smoke or fog. We also studied a beam-scanning technology for reducing this camera's frame interval. The camera uses a receiving antenna composed of a frequency scanning antenna and a reflective mirror.

### 3.1.1 "Flexible" production systems

We are researching a distributed broadcast station that automatically makes available production resources, such as equipment and video materials, on a computer network and allows program editors to build their own program production environment anywhere they desire.

In FY 2008, we developed middleware for organizing and managing the program editing system through a distributed computing model based on an open standard of grid computing. We also developed a Web interface for program editing, which works by calling middleware functions via a Web browser. Using this interface, editors can build their own program production environment wherever they are.

We are developing a widely distributed server system for sharing of a huge quantity of video material and high-speed file transfer technology that enhances the task of editing on the production system. Regarding the widely distributed server system, we developed a fault-tolerant peer-to-peer (P2P) file-management method that eliminates the chance of a single point of failure (SPOF) and that reduces network traffic between distant servers. We verified this system in tests with

10,000 server processes. Additionally, we developed a new distributed file management system that is compatible with the directory management systems of existing operating systems. This file system can be easily expanded by adding access control functions, etc., because the file management information is described in XML.

Regarding the high-speed file transfer, we developed a new file transfer protocol that controls transfer rates according to the priority of each file. This protocol expands the functionality of the synchronous transfer protocol developed in FY 2006. Another development was a rapid file

modification system that combines two new techniques: one which quickly detects differences between two files by using a hash function message digest, and another which adds new functionalities for partially inserting, deleting, and overwriting files.

This system reduces the file update time so that programs can be revised up until they are broadcast. This system was exhibited at the STRL Open House (Figure). Our work on tapeless broadcast systems is being carried out in collaboration with the Engineering Administration Department of NHK and various manufacturers.



Experimental file-transfer equipment

### 3.1.2 Broadcast distribution/contribution using optical wavelength division multiplexing

We are researching Super Hi-Vision transmission technology using optical fiber. To improve the long-distance relay characteristics, we performed simulations on compensating for the chromatic dispersion and non-linear distortion affecting fiber-optic transmission paths. The results revealed the relationship between distortion compensation and lookup-table size.

NHK is participating in research on an ultra-high-speed optical LAN-SAN system under the "Next Generation High-efficiency Network Device Technology Development" project of the New Energy and Industrial Technology Development Organization (NEDO). In FY 2008, we designed the format for transmitting Super Hi-Vision signals over 160 Gbps optical LAN and confirmed that the hardware can perform signal processing at up to 10 Gbps. We also prototyped an

interface (Figure 1) for transmitting full-resolution Super Hi-Vision signals over a single fiber-optic connection between video devices. The interface uses dense wavelength division multiplexing of eight 10-Gbps optical signals with wavelength spacings of 0.8 nm.

As part of our cable-television research, we are developing base-band high-capacity distribution technology using time-division multiplexing (TDM) for fiber-to-the-home (FTTH) digital broadcast distribution. In FY 2008, we compared the costs of this technology with those of conventional frequency-division-multiplexing (FDM) broadcast distribution systems. We found that since the unit cost of optical amplifiers is high relative to that of optical splitters, the cost of TDM could be as low as 20% to 25% of FDM. We are also developing technology for distributing

broadcast signals over existing coaxial cables in buildings where optical fiber does not reach all dwellings or rooms.

The digital signal (MPEG-2 TS transmitted by optical fiber) is remodulated for distribution when it enters a building. We prototyped a cost-effective device with fewer phase lock loops (PLLs) for remodulation and conducted laboratory transmission tests on it.



Prototype interface

### 3.2.1 Three-dimensional video recording and playback technologies

STRL is conducting research on new imaging technologies for viewing subjects from various directions, with the goal of applying them to video production and three-dimensional television.

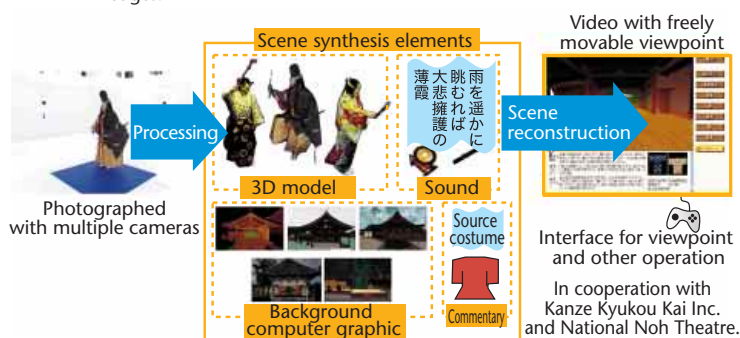
We are continuing work begun in FY 2006 on a prototype multi-view-point Hi-Vision system. The system uses 12 Hi-Vision cameras arranged in an arc, and the image appearing in the video is switched sequentially from each camera to give the illusion of camera movement around the subject. In FY 2008, we began a collaboration with the Nagano broadcasting station to develop a method for synthesizing the path of a hit baseball from multi-point Hi-Vision video. This method computes the ball's position in space from the video of the two cameras at either end of the camera array and uses the result to draw its path in the images from all of the cameras. This provides an easy-to-understand representation from various directions of the ball's motion.

Our research related to a 3D video archiving of traditional performing arts for the Ministry of Education, Culture, Sports, Science and Technology began in FY 2004. We are developing a system to generate 3D models of a subject shot by multiple cameras arranged around the subject. In FY 2008, we devised a method for generating the 3D model using the graph-cut method.\* To apply the graph-cut method, a set of 3D virtual points are set around the

subject, and the edges connecting them are given an 'energy' value expressing the likelihood of them being on the surface of the subject. This method reproduces an accurate form while maintaining its continuity. To create 3D video archive content, we generated 3D models of two Noh performances and computer graphics of the Takigi Noh stage at Sensoji Temple in Asakusa.

The 3D model contains the shape data for the subject, so it can be transformed into 3D video. Before FY 2008, we had studied methods for converting 3D models into 3D integral video using ray-tracing. In FY 2008, we developed a high-speed conversion technique making use of graphics processor units (GPUs).

\* A method which bisects a graph by minimizing the 'total energy' of cut edges.



3D video archive system for traditional dance

### 3.2.2 Technology for efficient video composition processing

Dramas and other programs require high-quality filming, compositing, and processing, and there is a need to make these activities more efficient and of higher quality. We began research into video composition technology for improving the quality of recording and processing work and increasing the efficiency of studio work.

To improve the source video, we improved camera and lighting technology. This in turn improves the quality of video compositing after filming. We increased the dynamic range of recorded video by using a camera with multiple image sensors. We also developed test equipment for light-ray control that maintains the desired lighting conditions when filming the subject.

We assume that better processing will result in video with a

wider dynamic range. To optimize wide dynamic range video to television displays, we performed simulations on tone mapping.\*

To increase the efficiency of studio work, we created a device to show performers the position and motion of virtual objects in the studio. The device uses small, high-intensity LEDs that are illuminated only during intervals when the camera image sensors are not exposed to present information to performers without it appearing in the composited video. The device was used in the "Himitsu no chikarando" program to create a natural-looking composite in which the position and timing of randomly appearing computer graphic bamboo shoots were displayed and the actor performed an ad-lib attempt to exterminate them (Figure).

In 2007, we developed a video compositing system using infrared light. This year, we used it during the "Three Little Pigs" virtual puppet presentation at the NHK STRL Open House. Infrared photography was used to make the key for compositing. This eliminated the previous color restrictions on the puppets.

We also improved the quality of composite video content by using high-precision compositing technology to compensate for lens distortion. We presented the Siggraph Asia 2008 Art Gallery with a video of the virtual puppet theatre.

\* Processing for modifying brightness and color.



Example of using electronic display device in a television program ("Himitsu no Chikarando")

### 3.2.3 High-functionality robot cameras

Robot cameras have the potential for more efficient program production and new forms of expression. We envision a studio program production system in which mobile robot cameras automatically decide and coordinate their shooting positions and perform composition and collaborative camera work. We are also working on a robotic camera system for use outdoors. This robot camera will be able to detect and track fast moving subjects automatically.

In FY2008, we developed a neural network machine-learning system that can learn the camera techniques of professional operators. The learned network can be used to control the robot cameras. Television programs cover a wide range of genres, and analyzing all the techniques employed in them would entail a huge effort. A machine-learning system can reduce the amount of effort; the camera operator simply shoots with the robotic camera, and the neural network learns the operator's technique used for the particular scene.

We performed tests to confirm that camera techniques such as panning shots can be reproduced by the system after it has learned the camera operator's technique.

We continued with our research on mobile robot camera position calibration for a computer graphics compositing system. In FY2008, the system was used in programs such as "Close-up Gendai" and in Beijing Olympics coverage (Figure 1). We improved its operability and verified its stability in cooperation with the Broadcast Engineering Department. The Beijing Olympic coverage lasted 17days (22hours per day).

The computer graphics were added to images by using the robot camera's position calibration function. This position calibration function was also incorporated in the camera in the newly refurbished studio 411 .

We are developing an off-road autonomous camera carrier based on a Segway®. In FY 2008, we equipped the carrier with an infrared camera and laser range finder for automatically detecting and tracking subjects. The infrared camera detects the body heat of a human or animal being photographed, and the laser range finder calculates the direction and distance. The camera's position calibration function was also shown to be useful for determining the robot's location from landmarks.



Operations during Beijing Olympics coverage

### 3.2.4 High-quality speech synthesis

We are studying high-quality speech-synthesis technology that automatically converts a manuscript into speech for broadcast and automatically reads out on-screen news flashes about earthquakes and other data broadcasts for visually impaired viewers.

In FY 2008, we studied automatic speech synthesis of new company names and place names, for which only a limited amount of recorded speech would be available. The synthesized speech is manually improved if it is of poor quality. Editing includes operations such as replacing units of synthesized speech or matching the voice pitch of a speaker with an appropriate accent. Subjective evaluations of the automatically synthesized company names indicated that approximately 20% were of good quality. The remaining poor quality speech was manually edited, and this resulted in improvements to over a third of the synthesized spoken names. Hence, approximately half of the spoken names were regarded as good quality.

We continued to study speech synthesis of meteorological reports for fishermen. These reports tend to contain long and complex sentences, and it is difficult to produce speech with a natural sounding intonation by recording discrete words or short phrases and stringing them together. Instead, we reduced the number of recorded sentences by recording phrases having the same structure and the same words in the same places only once. In so doing, the intonation of the sentence would be more likely preserved even when terms

within the recorded sentence are replaced.

We also continued our research on combining different persons' voices in concatenative speech synthesis to be used when the speech database lacks appropriate synthetic units. We discovered that replacement of certain phonemes in a short sentence with those from another person can be made less detectable if the characteristics in the frequency bands below 1 kHz and above 3 kHz are considered when selecting the phonemes.

We also continued our development of voice-anonymization equipment (Figure) from FY 2007 and used the equipment on a daily basis in News Center broadcasts. We also developed and tested new methods for reducing distortion that occurs when background noise is suppressed.

Some of the above research was done in collaboration with NHK-ES.



Voice anonymization equipment

### 3.2.5 Organic image sensors

We are developing a single-chip organic color image sensor with stacked layers of organic photoconductive film sensitive to each of the three primary colors and transparent circuits for reading out the electrical charge signals generated by the photoconductive film. This development will lead to a compact Super Hi-Vision camera. In FY 2008, we prototyped sensor devices for two of the three colors to perform basic testing and verified that color images can be obtained with these organic sensor devices.

In the prototype imaging device, separate organic films sensitive to green (G) and red light (R) are individually formed on thin-film transistor (TFT) circuits that are transparent to visible light (Figure 1); first green and then red elements are stacked in the direction of the incident light. The green organic film uses quinacridone and perylene derivatives as the photoconductive material (peak photocurrent at a wavelength of 540nm), and the red

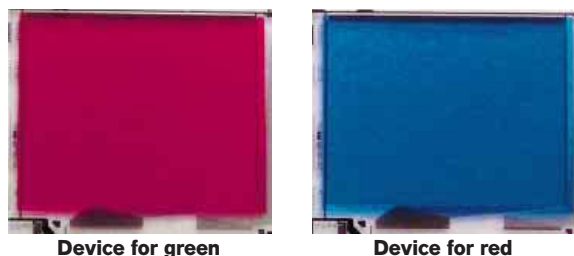


Figure 1. Prototype test imaging devices

organic film uses a phthalocyanine derivative (peak photocurrent at a wavelength of 700nm). A potential is applied to the red films through the bottom aluminum electrode (the bottom electrode does not need to be transparent) and to the green film on the incident-light side through a transparent indium-tin-oxide electrode. A zinc-oxide (ZnO)-TFT circuit was used to read out the charge generated by the organic films. It too is transparent. The prototype had approximately 1500 pixels, with pixel pitch of  $600\mu\text{m}$ .

We verified that the green component of the incident light can be imaged by the green elements and the red component that passes through the green element can be imaged by the red elements (Figure 2). The results also indicated that a color-imaging device can be constructed of three organic films stacked with transparent TFT read-out circuits. The prototype device had resolution essentially the same as the number of pixels in the ZnO-TFT circuit, so a high-resolution device should be possible by increasing the number of pixels and level of integration of the TFT circuit.



Figure 2. Sample image from prototype device

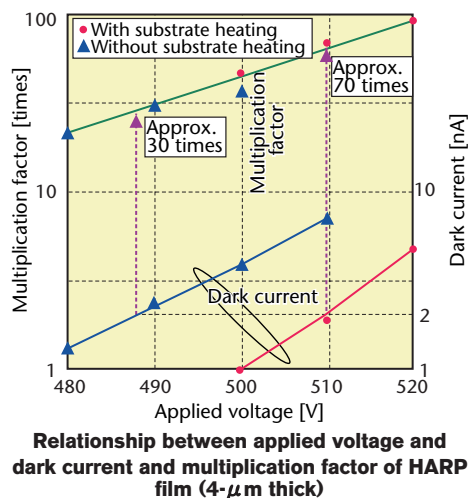
### 3.2.6 Super high-sensitivity image sensors

We are researching a field emitter array image sensor with HARP film in an effort to build a compact, super-high-sensitivity Hi-Vision camera. In FY2008, we made efforts to reduce the size of the image sensor and to improve the effective sensitivity of the film.

To reduce the size of the image sensor, we have been developing an electro-static focusing system focuses the electron beam from the field emitters by applying a voltage to focusing electrodes on the field emitter array, instead of using a focusing magnet or coil. Several electrostatic focusing systems have already been proposed for use in field emission displays (FED) but all suffer from the problem that the beam current becomes extremely low as the electron beam becomes more focused. This has made it extremely difficult to apply them to image sensors, which have much small pixels and require a lot of electrons to operate. Thus, for a standard 2/3<sup>rd</sup>-inch TV image sensor with  $640 \times 480$  pixels measuring  $13.75\mu\text{m} \times 13.75\mu\text{m}$ , we began development of a Spindt-type electrostatically focused emitter array that would have good resolution and a good dynamic range. The design of the focusing electrodes is almost complete. We are also designing

the emitter array, internal driving circuits, and image sensor.

On another front, we have been working on reducing the dark current of HARP film to improve its effective sensitivity. The photo-generated charge in the amorphous selenium of the HARP film is multiplied by the avalanche multiplication phenomenon, and the multiplication factor (sensitivity) can be remarkably increased by increasing the voltage applied to the film. However, the dark current also increases when doing so, degrading image quality, so the maximum voltage that can be applied, and in turn the maximum effective sensitivity, is limited by the dark current.



To reduce the amount of external hole injection, which is one of the factors contributing to dark current, we reexamined the conditions for forming the cerium oxide ( $\text{CeO}_2$ ) layer, whose role is to block hole injection into the HARP film. We discovered that by heating the glass substrate during vapor deposition of the  $\text{CeO}_2$ , the dark current could be reduced to approximately 25% of values obtained without heating the substrate. This allows the maximum voltage applied to the film to be increased and the effective sensitivity of the HARP film to more than double (Figure).

### 3.2.7 Ultra-high-speed camera

We are conducting research on an ultra-high-speed, high-sensitivity CCD and camera able to take bright images under normal lighting conditions of momentary phenomena not visible to the naked eye. Earlier, we developed a 300,000-pixel ultrahigh-speed CCD (up to 1million frames/sec) and single-sensor color camera using it.

The performance of this camera is unprecedented in terms of frame speed and sensitivity, but it is only able to record 144 frames.

In FY 2008, we began working on increasing the number of frames while maintaining the frame speed and sensitivity by using two ultra-high-speed CCDs and a beam splitter.

The two CCDs are attached to the two outputs of the beam splitter. They are driven by separate FPGAs<sup>\*1</sup> connected to a controller PC, so that capture conditions, such as speed, can be configured individually. The timing signals to start capturing images are adjusted and sent sequentially to the CCDs by the FPGA, allowing the number of recorded frames to be doubled.

With this structure, the light incident on each CCD is reduced by half due to the beam splitter. However, the light-collecting efficiency can be more than doubled by using the ultra-high-speed CCD on-chip micro-lens array developed in FY2007, so this combination allows the recording time to be doubled without reducing camera sensitivity. To accommodate the ultrahigh-speed CCD, which is 41mm diagonally, a beam splitter (cube shaped) with sides of 44mm or greater is needed. The F-Mount<sup>\*2</sup> of this camera has a flange focal distance of 46.5mm, so

it was difficult to add additional shutters or IR-cut filters if needed. This problem was solved by using glass with a high refractive index of 1.72 for the beam splitter (normal glass is 1.52), reducing the effective optical distance to 25.6mm. The F-mount was used because of the size of the CCD imaging surface and the wide variety of lenses available.

\*1 FPGA: Field Programmable Gate Array

\*2 F-Mount: A large-diameter mount used mainly for film cameras with a 44 mm throat and flange focal distance (distance from the back of the lens to the imaging surface) of 46.5 mm.



Prototype ultra-high-speed camera

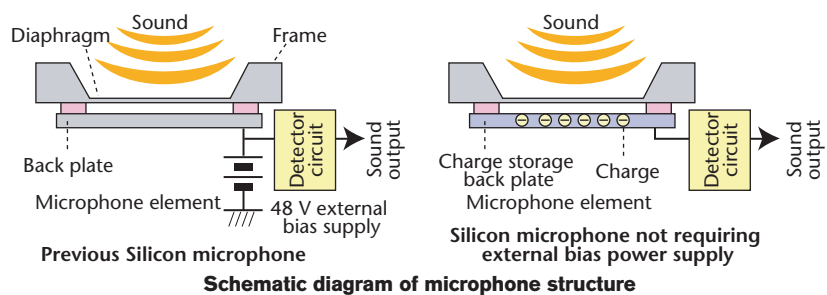
### 3.2.8 Silicon microphone

We have been conducting research and development on a silicon microphone fabricated out of high-mechanical-strength single-crystalline silicon. The objective is to create a mass-producible, compact and reliable high-performance microphone using semiconductor processes. We have confirmed that the silicon microphone satisfies sound-quality requirements for broadcast and does not suffer from problems of conventional microphones, such as susceptibility to heat and humidity. In FY 2008, we conducted field tests and looked for a way to remove the external bias power supply and improve operability.

In a field test, we placed the microphone near the water's surface in a swimming competition. The microphone performed well for the duration of the competition, even though it was continually being splashed with water. The microphone was also used in medical experiments to record the voice input for an amplifier system for patients who have difficulty speaking because of pharyngeal ablation. Its small size and excellent resistance to humidity and pharmaceuticals made it particularly suited for this role.

The silicon microphone requires a bias voltage to detect a sound signal, and sensitivity increases as the bias voltage increases, so until now, it has used a standard 48 V broadcasting power supply. However, the external bias power supply

should be removed in order to exploit its small size fully. Thus, we began developing technology to store a charge within the microphone so that it could be used without an external bias power supply. Although the diaphragm and the back plate are both possible locations to store a charge in the microphone, we decided to stack a charge storage layer onto the back plate because it would have less of an effect on the acoustic characteristics of the microphone. We decided to use a silicon-based material for the layer because of its physical and chemical stability and resistance to heat and humidity. So far, we have confirmed that it is possible to stack a charge-storage layer onto the back plate, to store a charge on it using the discharge phenomenon, and to keep this charge stable even at high temperatures. In the future, we plan to increase the stored charge and to confirm operation of the microphone with the stored charge.



### 3.2.9 Optical functional devices for archives

We are developing optical readers for magnetic tape and fast, high-capacity optical disks for efficient and stable storage of archival content.

#### Optical reading of magnetic tape

We are researching technology for fast optical reading of magnetic tape, for the purpose of converting content recorded on magnetic tape into video files and rapidly copying them to next-generation media such as optical disks. Our method uses the Faraday effect (a phenomenon by which the polarization of reflected light is rotated on the basis of the direction of magnetization of the film) to transfer multiple tracks on the tape to a magnetic garnet film. In FY2008, we improved the garnet and reflective films and successfully transferred magnetic patterns of data in D-

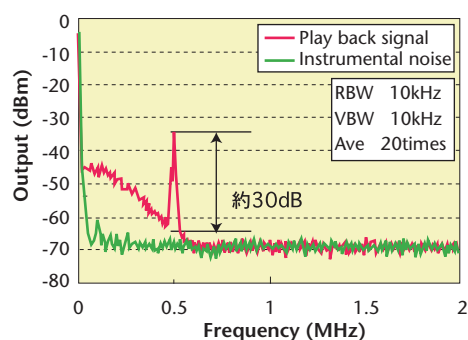


Figure 1. Example of playback spectrum (recorded wavelength: 0.77 μm)

3 format to them. We also prototyped equipment to play back a single track using a laser and confirmed that a signal of the shortest recordable wavelength in D-3 format of 0.77 μm could be read with a CN ratio of 30dB or higher (Figure 1). We are also designing and prototyping the optical reading system for multi-track playback.

#### Thin optical disk

We are conducting research on a thin optical disk with a 0.1mm substrate and developing a disk drive for it. This disk is intended as a video recording media to replace magnetic tape in broadcast stations and for storage (archiving) of Hi-Vision video. In FY2008, we improved the flatness of the disk and the recording sensitivity. We achieved a 250-Mbps recording and playback capability using a zero-phase-error tracking servo, and we built a high-speed partial response maximum likelihood (PRML) signal processor to reduce symbol error rates to less than  $2 \times 10^{-4}$ . We also found that adding the aerodynamic stabilizer for the flexible optical disk to a commercial Blu-ray disk drive enabled the drive to record and play back MPEG-2 Hi-Vision video at a data-transfer rate of 100Mbps (Figure 2). We also began development of cartridge and changer mechanisms for disk drives using flexible optical disks.



Figure 2. Experiment recording and playing-back Hi-Vision video with prototype drive

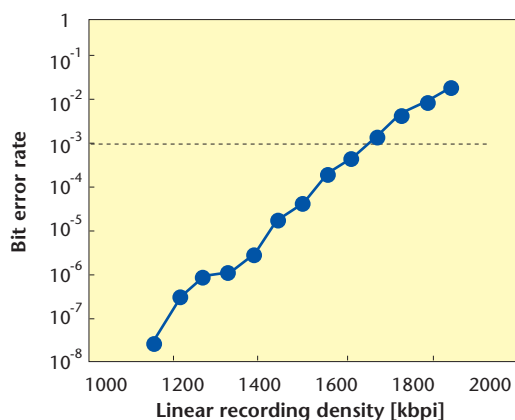
### 3.2.10 High-speed hard disk drive for recording video

We are conducting research on high-density magnetic recording with the aim of developing a hard disk drive for recording uncompressed Hi-Vision video. In FY2008, we increased the recording density of perpendicular magnetic disks and began research on thermal-assisted magnetic recording (TAMR).

We fabricated multi-layered CoPtCr-SiO<sub>2</sub> granular-type perpendicular magnetic disks and improved the recording layer by adjusting the magnetic interaction between the constituent layers. The resulting overwrite characteristic of under -30dB, high thermal stability, linear recording density of

over 1600kbpi, and bit error rates below  $10^{-3}$  meet the requirements for practical use (Figure). A disk rotating at 15,000rpm should be able to record uncompressed Hi-Vision video at rates of 1.5Gbps or higher.

The size of magnetic grains that compose the recording layer can be reduced in order to increase recording density, but this degrades the thermal stability of the recorded magnetization. This degradation can be controlled by increasing the magnetic anisotropy of the magnetic grains, but that also makes writing more difficult because the maximum magnetic field possible with the magnetic writing head is not sufficient to overcome the large magnetic anisotropy of the media. As a potential solution to this problem, we have begun studying TAMR, in which a local area of the media is heated with a laser to reduce the coercivity to a level writable by current magnetic heads. We experimented with a granular perpendicular magnetic media with a coercivity of 9.6kOe; conventional heads cannot write on this media. Results showed that almost no recording without thermal assistance, but that playback output increased by more than 15dB with thermal assistance. Moreover, by varying the relative positions of the laser and recording head, the maximum playback output was achieved when the laser was positioned at the leading edge of the recording head.



Dependence of bit error rate on linear recording density

### 3.2.11 Measuring the viewer's state of mind

We are researching techniques for measuring viewers' psychological state in order to objectively analyze the psychological effects of television programs on viewers.

In FY 2008, we continued our research using functional near infra-red spectroscopy (fNIRS) and functional magnetic resonance imaging (fMRI) to measure brain activity and developed an apparatus for tracking the gaze of multiple viewers simultaneously.

We measured brain activity using fNIRS while the subjects performed a task requiring their attention to be continuously focused on particular locations in moving images. The results showed that there was no difference in task performance regardless of which visual half-field (left or right) the person's attention was directed to, but there was a difference in brain activity. When attention was directed to the left visual half-field, brain activity increased with the degree of attention, but activity did not change much when attention was directed to the right visual half-field, indicating an asymmetry between the left and right visual fields in the relationship between the degree of the attention and brain activity. This asymmetry in brain activity with respect to visual field was observed in all of the posterior cortices, including the posterior parietal cortex and lateral occipital cortex. Our analysis suggests that this asymmetry is due to differences in the strength of mutual



**Simultaneous gaze tracking system for multiple viewers**

inhibition between the left and right cerebral hemispheres, and this knowledge will be useful in future development of methods for measuring the state of attention.

In order to measure where and how much of a viewer's attention is directed at a television program, we should have a probability distribution of the viewer's gaze toward the program. To create such a distribution, we have to gather a large amount of gaze data from many viewers. To make the collection process easier, we built equipment to collect viewer gaze data efficiently. The pupil-corneal reflection method illuminates both eyes with near-infrared light and captures the reflected light with a high-resolution camera. It then calculates the fixation point through image processing. Although it would be possible to increase accuracy by zooming in on a single eye, both eyes are captured and the image of each eye is processed independently to ensure the stability of the measurement even when the viewer moves his/her head in a normal seated posture. By controlling five such capturing and processing systems through a network, the gazes of five viewers can be tracked simultaneously, and data-collection efficiency can be improved. In the future, we plan to collect gaze-tracking data on various programs and devise objective evaluation methods using statistical metrics obtained from the data.

### 3.3.1 Millimeter-wave mobile camera

Our research on millimeter-wave mobile cameras has the goal of creating a wireless Hi-Vision camera for studio use.

At the 2008 STRL Open House, we exhibited a Hi-Vision video transmission system with a 55-GHz-band millimeter-wave mobile camera, multiple-input/multiple-output (MIMO) modulation/demodulation with two transmitters and four receivers, and equipment that automatically selects four of the eight receivers with the best reception.

In July, we conducted transmission tests with the 55-GHz-band millimeter-wave mobile camera in the 330m<sup>2</sup>-class CT-501 studio used for news programs and confirmed that uninterrupted transmission was possible in almost all areas of the studio.

We also demonstrated completely wireless operation of a robotic camera by combining it with the millimeter-wave mobile camera. We created a prototype 42-GHz-band high-frequency transmitter component capable of ten-times the output power of the 55-GHz-band device for covering areas larger than a studio, such as concert halls or stadiums. For environments with few reflections, such as outdoors, we expect it would be difficult to separate the MIMO signals, so instead of MIMO, we made improvements to allow the use of four-branch maximal-ratio combining with one transmitter and four receivers. We performed transmission experiments in NHK Hall and STRL Grand, verifying stable transmission at distances up to 100 m.

In December, we obtained a mobile station license for 42-

GHz and 55-GHz bands so the millimeter-wave mobile camera can be used for actual television programs. At the 59th NHK Annual Song Festival at the end of the year, the 42-GHz-band millimeter-wave mobile camera using maximal-ratio combining was used in a program together with a steady-cam (a camera-support device used to prevent camera shake) for the first time and provided stable wireless transmission for shooting a total of ten mobile scenes on stage and in the audience area (Figure).



**Scene from rehearsals for the NHK annual song festival**

Research results on channel coding systems including MIMO are compiled in the Association of Radio Industries and Businesses standard entitled, "Portable millimeter-wave digital transmission system for television program contribution" (ARIB STD-B43).

### 3.3.2 Reliable wireless transmission technology

#### Increasing efficiency and reliability of 800-MHz-band FPUs

We are interested in enhancing the spectrum efficiency and transmission reliability of 800-MHz-band field pick-up units (FPU) used for on-site road-race coverage.

As for multi-input multi-output (MIMO) technology that shows good performance in low-correlation environments, we studied techniques for maintaining transmission quality despite there being high-correlation paths in line-of-site environments. The study was based on MIMO transmission experiments done in urban areas in FY 2007. Experiments using orthogonal polarization MIMO transmission showed that this form of transmission was more reliable than MIMO transmission using only a single polarization, even in line-of-site environments. We also devised a low density parity check (LDPC) coding MIMO encoder/decoder that reduces correlation in the received signal by generating a soft replica of the interference stream (another transmitted signal that differs from a desired transmitted signal) and iteratively eliminating it from the received signal. Through simulations, the method was shown to be effective for improving receiver characteristics in line-of-site environments. We devised a circuit architecture that does not introduce a loop delay due to time de-interleaving to perform the iterative elimination.

We conducted transmission tests using a space-time trellis code (STTC) MIMO method with two transmitters and two receivers and confirmed that this method also provides good transmission characteristics in line-of-site environments.

For error correction, we studied serially concatenated low-density generator matrix (SCLDGM) codes, which connect LDPC codes built from LDGMs. We proposed an original LDGM structure for SCLDGM code and confirmed through simulations that a coding gain of approximately 2 dB can be obtained relative to the combination of convolution coding in the current FPU and Reed-Solomon coding (Figure 1). This SCLDGM code was implemented in hardware.

We developed a video encoder that conforms to the AVC/H.264 High 4:2:2 profile. The coding experiments using the encoder verified that the image quality satisfies with the requirements of the FPU. We also developed post-processing equipment for the decoder, which has a function to reduce freezing of the decoded video when transmission errors occur.

Part of this research was sponsored by the Ministry of Internal Affairs and Communications as part of its project "Research and Development for advancement of mobile communications systems for live video material pick-up in the 800-MHz band".

#### Microwave-band digital FPU

We are continuing our research on high-efficiency, low-

distortion power amplifiers. In FY 2008, we prototyped a power amplifier circuit using the gallium nitride microwave-band transistor (GaN-HEMT) that we made in FY 2007. The circuit satisfied the ARIB standard regulations for side-lobe characteristics of OFDM digital FPUs in the 6.42 to 6.60 GHz frequency band, produced 5 W of output power, and had a power efficiency (final-stage drain efficiency) of approximately 10%. We also began a study of a base-station MIMO system for road-race signal relays.

#### Ultra-high-speed wireless transmission technology

Since FY 2006, we have been studying error correction and diversity receiving technology for ultra-high-speed wireless transmissions in the 120-GHz band. In FY 2008, we prototyped a forward error correction system using concatenated Reed-Solomon coding for 10-Gbps signals multiplexing six channels of uncompressed Hi-Vision video (Figure 2). The prototype was evaluated in laboratory tests connected to 120-GHz wireless equipment, and the results showed that compared with not using error correction, it should be possible to increase transmission distances by a factor of two. Field trials over

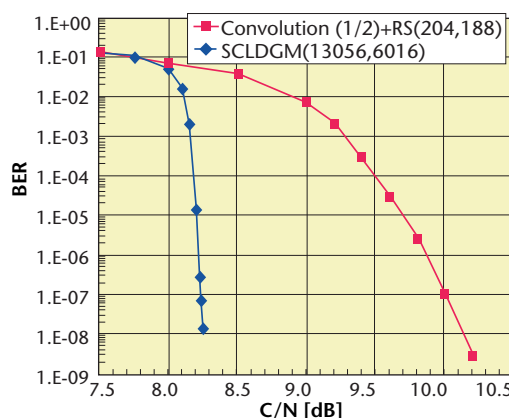


Figure 1. 16QAM-OFDM additive white Gaussian noise (AWGN) characteristics



Figure 2. 10-Gbps forward error correction system

transmission distances of 3 km showed that bit-error rates were usually approximately 10<sup>-6</sup> without error correction, while they were zero (error-free transmission) over long periods with error correction. Part of this research was sponsored by the Ministry of Internal Affairs and Communications as part of its project "Research and Development on technology for transmission of high-definition video over the millimeter-wave band".

We also began research on modulation/demodulation technology using high-speed digital signal processing that will one day enable wireless transmissions of Super Hi-Vision. In FY 2008, we prototyped a signal processing board incorporating GHz-class AD and DA converters and developed a high-speed processing program for the modulator/demodulator circuits.

#### Mesh reflector antenna for satellite news gathering

Depending on the circumstances, different types of antenna are used for on-site news reporting with the 14-GHz-band satellite news gathering (SNG) equipment. Compact antennas allow the first transmissions of emergency reports to be made as quickly as possible, while larger antennas are good for relaying live high-quality video. In FY 2008, we designed and prototyped an offset mesh-reflector antenna with aperture of diameter 0.9 m intended for emergency reporting. In spite of its small size, its emission pattern satisfies the ITU-R side-lobe standards for SNG earth stations.

### 3.3.3 Millimeter-wave TV camera

We continued with our research on a millimeter-wave TV camera that uses millimeter-waves to capture images of subjects obscured by smoke or fog. In FY 2008, we studied a beam scanning technology with a receiving antenna composed of a frequency scanning antenna and a reflector for increasing the camera frame rate.

First, we studied methods for increasing the scanning range of the frequency-scanning antenna, which performs the beam scanning by changing the frequency. This antenna is constructed with slanted corrugations located periodically on the bottom wall of the waveguide, and it receives the millimeter-waves through a slit in the top wall (Figure 1). The received waves propagate along the waveguide and corrugations, so by adjusting the angle and depth of the corrugations, the phase delay of the waves can be greatly altered according to the frequency, increasing the frequency scanning range of the receiving beam. Test results indicate

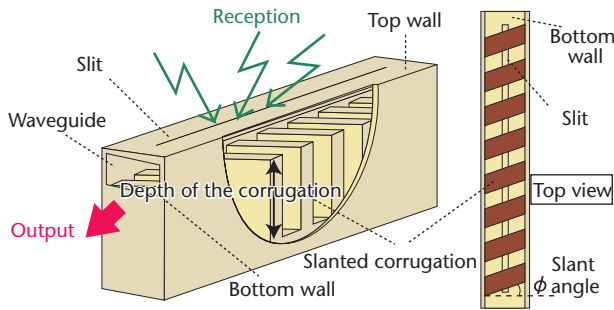


Figure 1. Structure of frequency scan antenna

that a beam scanning range of approximately 16-degrees should be possible for a frequency change of 60 to 62 GHz.

We also began research on a reflectarray antenna for two-dimensional electronic scanning. For the reflectarray antenna, the antenna reflector is divided into many small reflecting elements, and the phases of the waves reflected from each element are individually adjusted to form the desired antenna beam. The reflecting elements are composed of a microstrip patch and a stub loaded with a PIN-diode, and by switching the diode on and off, the reflected phase can be adjusted, allowing electronic scanning of the beam. We evaluated a reflectarray antenna of 40x40 elements (Figure 2) at an operating frequency of 60 GHz and confirmed that it was capable of electronically scanning in the range necessary for the millimeter-wave TV camera (around 50 degrees).

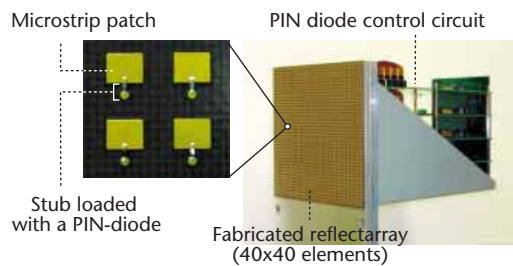


Figure 2. Reflectarray (array of reflecting elements) and control circuit

# International Cooperation and Collaboration

## Outline

New broadcasting media such as digital satellite and terrestrial broadcasting and Super Hi-Vision need to be promoted overseas and subjected to international standardization. For standardization to proceed smoothly, we should form international collaborations and build up trust in the early development stages. At present, we are collaborating with the European Broadcasting Union (EBU) and the Asia-Pacific Broadcasting Union (ABU), and we are promoting Japan's standard for digital terrestrial broadcasting, ISDB-T, in South America and elsewhere.

## 4.1 Collaborations with research institutes of European public broadcasters

In February 2007, STRL entered into a research and development agreement with the research institutions of European public broadcasters, including the BBC (UK), RAI (France), IRT (Germany), and the EBU (European Broadcasting Union). Under the terms of the agreement, we are to collaborate on researching and developing Super Hi-Vision coding and satellite transmission technology.

In 2008, we performed the first-ever international transmissions of Super Hi-Vision over IP and via satellite to audiences at the largest broadcasting exhibition in Europe, IBC2008. The international IP transmission was a live relay from London to Amsterdam, and the international satellite transmission was pre-recorded content transmitted by satellite from Torino to Amsterdam.

The experiment at IBC drew a lot of conference participants, and STRL received a special prize from IBC organizers. Together with the BBC and RAI, we presented a report detailing the test at the October assembly of the ITU-R. Through these activities, we demonstrated that research and development of Super Hi-Vision is being carried out with a high level of international cooperation by many organizations. We expect this will help our standardization activities and will contribute to eventual adoption of the technology.

Moreover, we are cooperating with European broadcasters in researching interactive broadcast services and broadband MIMO transmission technology. STRL also participated in an EC project called DTV4ALL. The objectives of the DTV4ALL project are to develop and promote broadcast accessibility technology for disabled and elderly persons.

## 4.2 Asia-Pacific Broadcasting Union (ABU)

The ABU technical committee's topics include making the

transition to digital broadcasting, introduction of HDTV, studio production, archiving, emergency broadcasting, broadcasting beyond HDTV (Super Hi-Vision), human resources development, and bandwidth allocation. NHK reports on these topics to the ABU Technical Operations Committee and the ABU Technical Committee. Since 2000, STRL has invited researchers from broadcasting stations within the ABU to conduct research at its facilities. Three ABU researchers were hosted by STRL in FY 2008 (Table 1).

In March 2008, at a digital broadcasting symposium hosted by the ABU, NHK staff gave presentations on emergency warning broadcasts, Super Hi-Vision, content protection, and ISDB-T. We also exhibited technologies such as automatic power-on for OneSeg. At the November 2008 meeting of the ABU Technical Committee in Bali, STRL staff submitted nine articles and presentations. The keynote presentation was by Keiichi Kubota, STRL Director-General. NHK staff also submitted ten reports on topics such as Super Hi-Vision and HDTV Advisories as part of investigative and research activities to the ABU technical committee. Our paper titled "Multi-channel sound system for future broadcasting" received an award from the ABU technical committee.

## 4.3 Digital terrestrial broadcasting

In June 2006, the government of Brazil decided to adopt the Japanese standard, ISDB-T, as the basis for its digital terrestrial broadcasting system, and in December 2007, digital terrestrial broadcasting began in Sao Paulo. Brazil has since expanded the broadcasting area. The governments of Brazil and Japan agreed that they should collaborate on technical and standardization matters and human-resource development. To discuss details of this collaboration, the Fourth and Fifth Brazil-Japan Cooperative Working Group meetings were held in Tokyo in June 2008 and in Brazilia in December 2008, respectively. STRL participated in meetings deciding standards for Brazil and created documentation showing the mutual compatibility of the two countries' standards in hopes that other South-American countries will adopt a form of ISDB-T.

Brazil's decision and the start of broadcasting there have had a great effect on other South American countries' deliberations on digital terrestrial broadcasting formats. The Digital Broadcasting Expert Group (DiBEG) was established to promote ISDB-T in South America and elsewhere, and it is collaborating with various governments. Through DiBEG, STRL is participating in seminars, demonstrations, and comparative field tests in various countries.

The major details of this collaboration during FY 2008 are summarized in Table 2.

Table 1. ABU Visiting researchers for FY 2008

Organization	Time period	Research theme
Islamic Republic of Iran Broadcasting	2008.9 - 2009.3	R&D on highly realistic future sound playback systems for television
All India Radio	2008.10 - 2009.1	System study for introduction of an emergency broadcasting system in India
Korean Broadcasting System	2008.11 - 2009.11	Research on methods to extract metadata and use it for searching program content

Table 2. Major details of collaboration with DiBEG activities in 2008

Date	Description
April 2008	Participated in a workshop on three digital terrestrial television formats held in Colombia. Performed demonstrations of outdoor mobile reception and indoor reception of ISDB-T test transmissions.
October 2008	Gave presentations and performed demonstrations of outdoor mobile reception and indoor reception of ISDB-T test transmissions in the Philippines. Participated in a digital terrestrial television presentation at CAPER 2008 (an international broadcasting equipment exhibition) in Argentina and performed indoor demonstrations of ISDB-T. Presentation on ISDB-T at the University of Palermo.
January 2009	Participated in ISDB-T field tests with the Argentinean National broadcaster. Participated in a three-format digital terrestrial television workshop in Ecuador. Performed demonstrations of outdoor mobile reception and indoor reception of ISDB-T test transmissions.

# Presentation of Research Results

## Overseas STRL Presentations and Contributions

### Overseas academic journals

IEEE Journals and Transactions	8
SMPTE Motion Imaging Journal	2
Applied Physics Letters	2
Journal of the Society for Information Display	2
Others	12
<b>Total</b>	<b>26</b>

### Overseas academic meetings and international conferences

IEEE International Conference	14
IDW*1	5
SPIE*2	6
AES*3	3
ISOM*4	3
IMID*5	2
Broadcast Asia	2
IBC*6	4
NAB*7	3
Others	57
<b>Total</b>	<b>99</b>

- \*1: International Display Workshop
- \*2: The International Society for Optical Engineering
- \*3: Audio Engineering Society
- \*4: International Symposium on Optical Memory
- \*5: International Meeting on Information Display
- \*6: International Broadcast Convention
- \*7: National Association of Broadcasters

## Public Relations

### Published Bulletins

NHK STRL publishes the following bulletins describing its research activities and achievements.

NHK STRL R&D features articles on topics such as ultra-high-resolution camera technology, applications of research results to TV programs, and high-density magnetic recording.

Broadcast Technology, which is published for overseas readers, introduces our latest research and includes topics such as intelligent processing technology, holographic recording, and the "Translation pallet" collaborative translation system.

### Website

Our website provides a broad range of information for both Japanese and overseas visitors, including an outline of STRL, annual research reports, STRL Open House and other event information, press releases, bulletins and patent licensing information. The site features introductions to each research group, with regular updates on their progress, and the site's top page posts articles from the "STRL Dayori" bulletin, so visitors to the site can conveniently read about our latest research results. We also have a page explaining the STRL Vision, "YOU".

### Publications for overseas readers



<http://www.nhk.or.jp/strl/english/index.html>



## Public Exhibitions

### Overseas Exhibitions

#### IBC 2008

At the largest broadcasting technology exhibition in Europe, IBC 2008, held in Amsterdam from Sept. 12 to 16, NHK STRL formed the Broadcast Technology Futures Group (BTF) together with the British Broadcasting Corporation (BBC), the Italian Broadcasting Association (RAI), and the European Broadcasting Union (EBU) and performed the first-ever international Super Hi-Vision transmission tests over IP and by satellite. For the IP transmission test, an international transmission from London to Amsterdam was done with cooperation from the BBC and the companies Siemens (communications system development), SIS (program production), and C&W (communications lines). For the satellite transmission, pre-recorded content was transmitted from Torino to Amsterdam with cooperation from RAI and Eutelsat.

Approximately 5,180 visitors including VIPs from various countries such as the British Minister of State for Trade and Investment watched the test programs in the Super Hi-Vision theater in Amsterdam. The programs were received very favorably by the audience. This exhibition demonstrated how Super Hi-Vision research and development is proceeding based on international cooperation, and the demonstration was reported around the world on BBC World TV and by other broadcasters.



#### Broadcast Asia 2008

NHK exhibited Super Hi-Vision for the first time in Asia outside of Japan, along with technology related to digital terrestrial broadcasting at Broadcast Asia 2008 exhibition held in Singapore from June 17 to 20. Approximately 4,490 visitors viewed Super Hi-Vision demonstrations over the four days, including ministers and vice-ministers in charge of telecommunications from various countries in Asia. The exhibition of technologies related to digital terrestrial broadcasting had many visitors, including those from countries that have not yet decided on a digital broadcasting format. Technologies such as One-Seg and a device for automatically activating a receiver for emergency broadcasting were also on display.



## NHK STRL Open House

The 62nd STRL Open House was held over four days from May 22 to May 25, 2008. This year's theme was "The power of technology: Bringing Changes to the World of Television."

The open house consisted of exhibitions divided into five zones and a poster exhibition. The "Frontiers of Broadcasting" zone introduced the whole Super Hi-Vision system, including the camera, signal coding, transmission, and household display systems. It also had exhibits describing the features of digital terrestrial broadcasting and outlining research aimed at creating a variety of new services. The new STRL Vision, called "You", was presented to the public, and zones presented the state of research corresponding to its themes of "Enhanced Reality Spatial Reproduction," "Useful and Universal Services," and "Environments for Producing Advanced Content." The "Utilization and development of broadcast technology" zone introduced the latest broadcasting technology, together with applications for medicine, science, industry, and education. The poster exhibition was oriented to specialists.



### Schedule

May 20 (Tuesday): Opening ceremony

May 21 (Wednesday): Open by invitation

May 22 (Thursday) to 25 (Sunday): Open to the public

No. of exhibits: 43 items

No. of visitors: 21,005 persons

## Addresses and research presentations

### Addresses

**Challenges for technological innovations in terrestrial digital broadcast services in the U.S.**  
Lynn Claudy (Senior VP, NAB)

**Positioning of research for RAI, the Italian public broadcaster, and collaboration with NHK**  
Alberto Morello (Director, RAI Research Centre)

**Our vision of broadcasting: Conveying feelings and new connectivity to viewers**  
Kenkichi Tanioka (Director General, NHK STRL)

### Research presentations

**Advanced Satellite Digital Broadcasting System (Special Presentation)**  
Shoji Tanaka (Broadcasting System)

**Thin Optical Disks**  
Daiichi Koide (Material Sciences and Advanced Devices)

**Ultra High Definition Light Modulation Device Driven by Spin Polarized Current**  
Ken-ichi Aoshima (Materials Science & Advanced Devices)

**New Digital Broadcasting Platform for Interaction with Home Network Devices**  
Akitsugu Baba (Broadcasting System)

**Fabrication of High Performance Organic Thin Film Transistor Array and Its Application for Flexible Displays**  
Yoshihide Fujisaki (Material Science & Advanced Devices)

**The Super Hi-Vision Codec System**  
Kazuhiisa Iguchi (Human & Information Science)

**Organic Image Sensors**  
Satoshi Aihara (Materials Science & Advanced Devices)

**Analysis of "Goodness" and "Kandoh" evoked by sound: Evaluation of Sound Based on Kandoh**  
Satoshi Oode (Human & Information Science)

## Exhibits

### Frontiers of Broadcasting

Frontiers of Broadcasting  
 33M-Pixel Image Technology  
 Image Sensor using Organic Compounds  
 Super Hi-Vision Codec System  
 Advanced Digital Transmission System for Satellite Broadcasting  
 Dirac: The New Coding Technology  
 Super Hi-Vision Home Theater System  
 Progress in Terrestrial Digital Broadcasting (ISDB-T)  
 Channel Equalizer for Echoes Outside the Guard Interval of OFDM Signals  
 Automatic Activation of One-Seg Receivers for Emergency Broadcasting  
 One-Seg Combined Retransmission System  
 High-Speed Mobile Reception Technique for HDTV Digital Terrestrial Broadcasting  
 Multi-level OFDM Technology  
 Activities for International Cooperation  
 Super Hi-Vision Theater



Organic Image Sensors



High-level Digital Satellite Broadcast System



Automatic Activation of Receivers for Emergency Broadcasts

### Enhanced reality spatial reproduction media

Integral Three-dimensional Television  
 Audio Devices for the Ultimate in Sound Reproduction  
 Psychological Evaluation of High-Presence Sound  
 Power-Saving Technology for Super Hi-Vision Plasma Displays  
 Satellite Broadcasting in the 21-GHz Band  
 High Dynamic Range Projector with 33-million-pixel Panel



Super Hi-Vision Theater

### Useful and Universal Services

AdapTV: A Context-aware Broadcasting Service  
 CurioView: New Viewing Style utilizing Information Retrieval  
 Broadcasting Security for Content Distribution Services via Communications  
 Advanced Receiver Platform for Interactive Services  
 TV4U (TV for You)  
 New Closed-Captioning System using Speech Recognition  
 Interactive Tactile Display  
 Flexible Displays



Next-generation Devices for the Ultimate in Sound Reproduction

### Environments for Producing Advanced Content

Advanced Studio Production Technology  
 Millimeter-Wave Mobile Camera  
 New File System for Transferring Program Files  
 Millimeter-wave TV camera  
 Thin Optical Disk  
 Ultrahigh-speed Camera  
 Multi-view HDTV System  
 Thin, Multi-joint Manipulator  
 New Type of Camera Stabilizer



Platform for Interactive Broadcasting Services

### Utilization and Deployment of Broadcast Technology

Ultrahigh-sensitivity HARP Camera  
 Watermarking that Survives Re-shooting  
 NHK Patents and Technical Expertise  
 TV Research at NHK Laboratories from 1930 to 1940  
 Digital Broadcasting Reception



Flexible Optical Disks

# Application of Research Results

## Cooperation with Program Producers

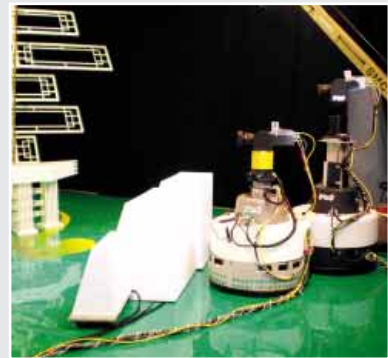
We cooperated with program producers in a total of 82 productions in FY 2008.

### Use of Robotic Camera in Beijing Olympic Programming

A robotic camera developed by STRL was used in some of the coverage of the Beijing Olympics (on Satellite ch. 1 from Aug. 9 to 25). The camera has a virtual studio function, and it was used in the reports from the on-site studio (350 hours of broadcast time). The camera was used in intervals between competitions, and computer graphic elements such as athlete photos or video were composited with the actual video shot in the studio. These composites showed viewers athlete profiles and competition results in an easy-to-understand manner.



Composite video with photograph and computer graphics (Today's Close-up)



Robotic camera

In the past, we have used robot cameras in field trials consisting of over 70 live broadcasts. They have been used in the programs "This Week and You," "Today's Close-up," and "NHK Special," and in reports from Expo 2005 in Aichi, Japan. Through the experience gained during these trials, we improved the usability and reliability of the cameras. There were no significant problems during the Olympic broadcasts, and operators enjoyed using the cameras.

### New Cameras used in the NHK Annual Song Festival

#### Millimeter-wave Mobile Camera

A millimeter-wave wireless mobile camera developed by STRL was used during the 2008 Song Festival. This camera digitally compresses the video it shoots before transmitting it via 42-GHz-band wireless. Compared with earlier wireless cameras, this camera has shorter delay of only one frame (approx. 33 ms), so that even close-ups of performers singing or speaking are in sync with the sound. The camera was used in ten scenes that required the cameraman to be on stage among the performers. A camera with wires is cumbersome to use under such circumstances, and its wires could easily interfere with the performance. The wireless camera's strengths were especially evident in scenes such as the 360-degree pan during Mika Nakashima's performance that showed the audience aglitter, and during Kimagure's performance in which the cameraman stayed among the dancers on stage. Wireless cameras are also safer during the commotion of complex set changes.



Scene from rehearsals

#### Hi-Vision HARP Camera

The ultra-high-sensitivity Hi-Vision HARP camera developed by STRL takes clear images in the dark. It was used during the Annual Song Festival to record a performance given in low light conditions. The stage and audience lights were turned down while host Yukie Nakama held candle lanterns and introduced singer Yo Hototo. Hototo's performance was illuminated with only 76 candles instead of stage lights. NHK Hall (the site of the festival) went almost completely dark, but the HARP camera captured clear images of the performers by candlelight. The HARP camera is a promising means of reducing energy consumed by studio lighting, and we will continue to improve its image quality.



Hi-Vision HARP Camera



Scene from rehearsals

## Patents and utility models

(NHK Total)

### Patent and utility model applications submitted

Type	New	Total at end of FY
Domestic		
Patents	316	1569
Utility models	0	0
Designs	2	0
Overseas	43	133
Total	361	1702

### Patents and utility models in use

Type	New	Total at end of FY
Contracts	40	274
Licenses (breakdown)	66	437
Patents	40	270
Expertise	26	167

### Patents and utility models granted

Type	New	Total at end of FY
Domestic		
Patents	262	1017
Utility models	0	1
Designs	2	9
Overseas	13	308
Total	277	1335

## Technical cooperation (NHK Total)

Type	Total
Technical cooperation projects	48
Commissioned research projects	8

# Joint Activities with the Overseas

## Collaborative Activities

### Overseas Collaborations

STRL conducted four instances of collaborative research in accordance with the mutual research collaboration agreement made in 2007 with the laboratories of European public broadcasters (BBC of the U.K., RAI of Italy, and IRT of Germany).

### Visiting Researchers, STRL Staff Overseas

Our program to invite young researchers from facilities affiliated with the Asia-Pacific Broadcasting Union (ABU) continued in 2008, with researchers from Iraq, India, and Korea accepting offers to conduct research at STRL.

Moreover, STRL researchers were dispatched to the U.S.A and the U.K. to conduct research at institutions in those countries.

## Contribution to International Standardization Organizations

### ITU-R

#### SG6

#### Broadcasting service

- Proposed revision of Recommendation ITU-R BT.1368 to include ISDB-T receiver C/N performance in pedestrian and mobile channels (WP6A)
- Mobile reception with four-branch space diversity for ISDB-T (WP6A)
- Multiplexing scheme for variable length packets (WP6B)
- Proposed revision of Recommendation ITU-R BT.1699 on harmonization of declarative content format for interactive TV applications (WP6B)
- Proposed draft new Question on ultra high definition television (UHDTV) (WP6C)
- Proposed framework of work plan for the study on ultra high definition television (WP6C)
- Proposed new Report on multi-channel sound technology in home and broadcasting applications (WP6C)
- Metadata for broadcast operational monitoring (WP6C)

#### Leadership

Study Group 6  
Vice-chairman  
Yukihiro Nishida  
WP6B Chairman  
Yukihiro Nishida  
WP6C Rapporteur  
Masayuki Sugawara  
Kaoru Watanabe

#### SG4

#### Satellite service

- Proposed revision of Recommendations ITU-R BO.1659 and BO.1776 and Report ITU-R BO.2071 on the broadcasting-satellite service in the 21 GHz band (WP4A)

Rapporteur  
Kazuyoshi Shogen

### ITU-T

#### SG9

#### Integrated Broadband cable networks and television and sound transmission

- Proposed revision of ITU-T Recommendation J.201 on harmonization of declarative content format for interactive TV applications

Rapporteur  
Masaru Takechi

### SMPTE

#### SMPTE

#### TV Engineers Meetings

- Establishment of the new standard SMPTE 2036-1, "Ultra high definition television - Image parameter values for program production"
- Establishment of the new standard SMPTE 2036-2-2008, "Ultra high definition television - Audio characteristics and audio channel mapping for program production"
- Proposed draft new standard, "Ultra high definition television - Mapping onto Multilink 10Gb/s Serial Signal /Data Interface"

### MPEG

#### MPEG-7

#### Multimedia content description interface

- Contribution for MPEG Query Format (MPQF)
  - Completed the International Standard as a project editor

## AES

### SC-02-02

#### Standard Committee on Digital Input/Output Interfacing

- Contribution for revision of AES3-2003, " AES standard for digital audio - Digital input-output interfacing - Serial transmission format for two channel linearly represented digital audio data"
- Proposed draft revision of AES11-2003, "AES recommended practice for digital audio engineering -Synchronization of digital audio equipment instudio operations"
- Discussion on liaison with IEC/TC100

### TC-TB

#### Technical Committee on Transmission and Broadcasting

- Discussion on multichannel sound for future broadcasting
- Discussion on current status and issues of digital broadcasting

### TC-ARMS

#### Technical Committee on Audio Recording and Mastering Systems

- Discussion on audio recording for multimedia and future audio systems
- Discussion on emerging trends of audio recording and mastering systems

Chairman  
Kimio Hamasaki

## IEC

### TC100

#### Audio, Video and Multimedia systems and equipment

- Proposed draft new standard, " Audio, video and multimedia systems - General channel assignment of multichannel audio"

## EBU

### B/HDC

#### Project Group on Evaluations of HD Codecs

- Discussions on HDTV formats for delivery and AVC codec performance

### P/DISPLAY

#### Project Group on Flat Panel Displays

- Discussions on user requirements for flat panel displays in television production

### P/SCAIE

#### Project Group on Study of Content Analysis-based Automatic Information extraction for Production

- Discussions on current content analysis technology and evaluation

### P/Loud

#### Project group on Loudness for Broadcasting

- Discussion to create awareness of problem and available solution for loudness issues and to encourage the use of recommended practices of loudness measurement standard.

## ABU

### Technical Committee

#### Management of ABU Technical Committee

- Exchange of information on the implementation of digital terrestrial broadcasting in the Asia-Pacific region

### PSG

#### Planning and Strategy Group

- Report on the Key Performance Index on the EBU Technical Department activities

### CEN-WP

#### Content Exchange Network Working Party

- Exchange of information on available network and set-up of task group Production

### Production

#### Topic Area : Production

- Report on progress of broadcasting production area
  - Report on UHDTV (D-Cinema)
  - Discussions on current IPTV service and metadata(RTA)

### Transmission

#### Topic Area : Transmission

- Report on progress of broadcasting production area
  - Report on DTTB Coverage and Frequency Planning (T/DTTB)
  - Report on Mobile Digital Multimedia Broadcasting (T/MMB)
  - Report on the implementation of EWBS (Emergency Warning Broadcasting System) in the ABU region (EWBS)
  - Proposal on new project topic Deliver using Network and Content Protection.(DNCP)

### Spectrum

#### Topic Area : Spectrum

- Report on progress of spectrum area
  - Report on the results of WRC-07 relating to 21GHz band Broadcasting Satellite matters (BSS-HDTV)
  - Report on the implementation of HDTV in the ABU region (HDTV Advisory Group)
  - Report on the implementation of HDTV in the ABU region (HDTV Advisory Group)

TC Chairman  
Kazuyoshi Shogen

UHDTV Project Manager  
Masayuki Sugawara  
RTA Project Manager  
Kiyohiko Ishikawa

T/MMB Project Manager  
Masayuki Takada  
T/API Project Manager  
Masaru Takechi  
EWBS Project Manager  
Kazuyoshi Shogen  
DNCP Project Manager  
Kiyohiko Ishikawa

BSS-HDTV Project Manager  
Kazuyoshi Shogen

## Doctorates

Doctorates acquired in FY2008	10
Doctorate holders at STRL at end of FY2008	87

## Patent attorneys

Qualified patent attorneys at STRL at end of FY2008	2
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## Organization

### NHK Science and Technology Research Laboratories

April 2008 - March 2009

No. of employees: 249 (224 researchers) (end of FY2008)

**Director-General** Keiichi Kubota  
**Deputy Director-General** Takayuki Ito

**Executive Research Engineer** Yoshihiro Fujita  
 Toshihiro Nomoto

#### Planning & General Affairs

Research planning, research-related public relations, and collaboration with Japanese and overseas research institutes. General affairs, labor services, accounting, and facilities management  
 Director/STRL Deputy Director-General: Takayuki Ito

#### Patents

Patent rights management and technology transfer related to NHK's R&D findings

Director: Tadashi Nakayama

#### Broadcasting Systems

Network system technologies, terrestrial digital broadcasting technologies, satellite broadcasting and millimeter-wave broadcasting system technologies, collaborative ubiquitous service technologies for broadcasting and communications

Director: Kazuyoshi Shogen

#### Human & Information Science

Highly realistic video and audio, advanced content creation, video and audio processing technologies for user-friendly universal services, intelligent processing technologies

Director: Nobuyuki Yagi

#### Materials Science & Advanced Devices

Broadcasting-related device technologies for video capture, display and recording, next-generation device material technologies

Director: Taiichiro Kurita