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NHK Science & Technology Research Laboratories Outline ............... 52
NHK Science & Technology Research Laboratories (STRL), the sole research facility in Japan specializing in broadcasting technology and part of the public broadcaster NHK, is working to build a rich broadcasting culture through its world-leading R&D on broadcasting technologies.

Fiscal year 2015 marked the 90th anniversary of the start of radio broadcasting in Japan. In May, we performed an 8K broadcasting experiment using an actual satellite at our Open House; it was the world’s first 8K broadcasting. We also made progress in our development of 8K cameras and displays that support a high dynamic range (HDR) technology, which expands the range of brightness that can be shown in TV images. The revision of the Broadcast Law in 2014 also propelled NHK’s effort to explore new possibilities of broadcasting media by utilizing the Internet, as was demonstrated in experiments of simultaneous online broadcasting of TV programs.

In response to NHK’s corporate plan for FY 2015-2017, we established our laboratories’ latest research plan, NHK STRL R&D plan (FY 2015-2017), with the goal of creating broadcasting and services that open up new possibilities. During this period, we will focus on three core areas: imminent applications of “Internet utilization technology” and “8K Super Hi-Vision” and the future development of “three-dimensional television.” Our research projects will be supported by the two pillar concepts of “advanced content production technology” and “user-friendly information presentation” to evolve broadcasting technology and services into ones with higher quality and more advanced functionality.

While we will continue to collaborate with broadcasting and research organizations in other countries by conducting joint research and sharing our research results internationally, we will also play a leading role in developing cutting-edge broadcasting technology and services.

This annual report summarizes our research results in FY 2015, the first year of our three-year plan. It is my hope that this report will help you better understand NHK STRL’s research and development activities and enable us to build collaborative relationships that promote research and development. I also hope it will help you utilize the results of our efforts.

Finally, I would like to express my sincere gratitude for your support and look forward to your continued cooperation in the future.

Greetings

Toru Kuroda
Director of NHK Science & Technology Research Laboratories
8K Super Hi-Vision

NHK STRL is researching a wide range of technologies for 8K Super Hi-Vision (SHV) in preparation for the test broadcasting in 2016 and the launch of full-scale broadcasting in 2018. We conducted various evaluation experiments on high dynamic range (HDR) effects and display luminance. On the basis of the results, we developed the Hybrid Log-Gamma (HLG) system, which has high compatibility with the standard dynamic range, in cooperation with the BBC. This format was approved by the International Telecommunication Union, Radiocommunication Sector (ITU-R) as a new draft recommendation. We developed a video decoding LSI using MPEG-H High Efficiency Video Coding (HEVC)/H.265 that is compliant with the domestic SHV broadcasting standard. We also secured domestic and international standards for our channel bonding technology for cable TV to transmit SHV.

→See p. 4 for details.

Three-dimensional imaging technology

With the goal of developing a new form of broadcasting delivering a strong sense of presence, we aim to develop a more natural and viewable three-dimensional television that does not require the viewer to wear special glasses. To this end, we are researching integral 3D imaging technologies and display devices for 3D images. We prototyped direct-view 3D display equipment that has four 8K liquid crystal panels arrayed in parallel. This equipment can display 3D images that have about 100,000 pixels, four times as many as previous one. We continued with our research on spatial light modulators using spin transfer switching for electronic holography and developed a driving silicon backplane with a pixel pitch of 2 μm and its external drive circuit. We also prototyped a 2D spatial light modulator with light modulation element formed by tunnel magneto-resistance on the silicon backplane and evaluated its performance.

→See p. 19 for details.

Internet technology for future broadcast services

We continued researching technologies for utilizing the Internet, targeting new broadcasting services for the era in which broadcasting and telecommunications will be tightly integrated. In our research on broadcast-linked cloud services, we contributed to functional verifications and standardization of Hybridcast Technical Specifications ver. 2.0 published by the IPTV Forum and developed benchmark tests in order to promote Hybridcast. In our research on utilization of program information, we developed application programming interfaces (APIs) for the Linked Open Data (LOD) format, released program guide information in the LOD format, and prototyped educational applications using semantic web technology.

→See p. 23 for details.
Technologies for advanced content production

We progressed with our R&D on advanced program production technologies that include production technologies for new content services and wireless transmission technologies used for program contributions such as emergency reporting and live sports coverage. We developed interfaces for presenting producers and viewers with programs related to the keywords of the program overview and for enabling users to select a program or scene from a comprehensive view. In our research on bidirectional field pick-up units (FPUs) for high-speed wireless transmission of file-based video, we examined adaptive control for improving the throughput and preferred transmission control for live footage. We also prototyped an experimental device to verify the feasibility of multistage relays using bidirectional FPUs.

→See p. 30 for details.

User-friendly broadcasting technologies

We are conducting research on technologies for “user-friendly” broadcasting that is easy to listen to, view and understand, so that all people, including those with vision or hearing impairments and non-native Japanese speakers, can enjoy broadcast content and services. We studied sign-language CG translation with facial expressions for weather information. We developed a system for automatically generating sign language CGs from weather forecast data distributed by the Meteorological Agency and demonstrated through psychological experiments that the produced sign language CGs are fully understandable. In our research on opinion analysis technology, we developed a method for categorizing a large number of viewer opinions of programs by the similarity of their content. We also contributed to the program production of “Data NAVI” by developing a tweet analysis system.

→See p. 34 for details.

Devices and materials for next-generation broadcasting

We are researching the next generation of imaging, recording, and display devices and materials for new broadcast services such as 8K Super Hi-Vision (SHV) and three-dimensional television. In our work on 3D-structured imaging devices, we prototyped an imaging device with 128×96 pixels by stacking an upper layer that has a buried photodiode with less dark current and a pulse generation circuit and a lower layer that integrates pulse counters for each pixel. This prototype demonstrated the feasibility of a wide dynamic range imaging device with 16-bit output. We developed elemental technologies for a holographic recording technology such as high-efficiency dual page reproduction and prototyped a practical drive. We also developed elemental technologies for creating flexible large displays with a low-cost solution-based technique.

→See p. 39 for details.

Research-related work

We promoted our research on 8K Super Hi-Vision and other technologies in various ways, including through the NHK STRL Open House, various exhibitions, and reports. We also actively collaborated with other organizations and program producers. We contributed to domestic and international standardization activities at the International Telecommunication Union (ITU), Asia-Pacific Broadcasting Union (ABU), Information and Communications Council of the Ministry of Internal Affairs and Communications, Association of Radio Industries and Businesses (ARIB), and various organizations around the world. We exhibited our latest research results, such as 8K, for which test broadcasting is soon to start in 2016, and new broadcasting technologies utilizing the Internet at the NHK STRL Open House under the theme of “Countdown to the Ultimate TV!” The event was attended by 20,123 visitors. We also held exhibitions in Japan and overseas to increase awareness of our research results.

→See p. 43 for details.
NHK STRL is researching a wide range of technologies for 8K Super Hi-Vision (SHV), including video formats and imaging, display, recording, coding, audio and transmission systems. We will start SHV test broadcasting in 2016 and switch to regular broadcasting in 2018.

In our research on video formats, we conducted various experiments on high dynamic range (HDR) effects and display luminance. On the basis of the results of these experiments, NHK and the British Broadcasting Corporation (BBC) jointly developed the Hybrid Log-Gamma (HLG) system, which is compatible with standard dynamic range (SDR). Together with the BBC, we submitted a proposal on this format to the International Telecommunication Union, Radiocommunication Sector (ITU-R), which later agreed to a draft new Recommendation for HDR television. For wide gamut colorimetry, we developed guidelines for color rendering index values of LED lighting used in 4K/8K production. In relation to our work on interfaces for transmitting 4K and 8K signals, ITU-R also adopted ultrahigh-definition signal/data interfaces (U-SDI) in a Recommendation.

In our work on cameras, we developed a compact single-chip imaging system for full-resolution SHV that uses a 133-megapixel color image sensor. For full-featured SHV camera operating at a 120-Hz frame frequency, we improved characteristics of image lag and streaking noise of a 33-megapixel image sensor, and succeeded in making the camera system capable of HDR imaging. We also prototyped a back-illuminated test sensor with 33 megapixels that can operate at a 240-Hz frame frequency.

In our work on displays, we developed an HDR, 85-inch SHV liquid crystal display (LCD) with a high contrast ratio by using a high-efficiency backlight system and driving technology for controlling the luminance of each area of the image. We also developed compact LCD monitors (17.3-inch diagonal and 9.6-inch diagonal) for the purpose of adjusting and monitoring SHV video during program production. In addition, we are progressing with R&D on elemental technologies for large, sheet-type displays that incorporate highly efficient and air-stable organic light-emitting devices and thin oxide film transistors for high-speed driving.

We worked on improving a signal compression processing circuit and increasing the speed of a memory package for recorders. We developed a full-featured SHV compression recorder that can record video in 4:4:4 without chroma subsampling at a 120-Hz frame frequency.

In our work on audio, we devised and investigated a new coefficient for loudness measurements of 22.2 ch sound and contributed to the revision of an ITU-R Recommendation and the loudness operation guidelines issued by the Association of Radio Industries and Businesses (ARIB). We also developed a processor for generating 22.2 ch sound materials by upmixing stereo or 5.1 ch sound materials. We developed a 22.2 ch audio encoder/decoder using MPEG-4 AAC as an audio component of the SHV encoder/decoder. The decoder is equipped with downmixing and dialog control functions. We conducted an 8K satellite broadcasting experiment on the encoder/decoder. We also developed a loudspeaker frame with binaural processing that can be attached to an HDR, 85-inch SHV LCD.

Regarding video coding, we conducted the world’s first 8K satellite broadcasting experiment using an MPEG-H High Efficiency Video Coding (HEVC)/H.265 encoder and developed a video decoding LSI compliant with the domestic SHV broadcasting standard. We also conducted coding experiments on HDR and 120-Hz frame frequency video to verify performance. For the next generation of terrestrial broadcasting, we began developing a new video coding scheme using super-resolution techniques.

Regarding media transport technologies, we developed multiplexing equipment supporting MPEG Media Transport (MMT) and conducted transmission experiments using a broadcasting satellite. We also showed hybrid services that take advantage of broadcasting and telecommunications. One example is presenting different videos in synchronization with each other, while they are delivered in different paths. The other is seamless switching between content from broadcasting and from telecommunications. This switching enables presentation of content suited to each viewer. In addition, we contributed to the international standardization of the MMT-based broadcasting systems. These efforts led to the publication of a new Recommendation at ITU-R and MMT implementation guidelines at ISO/IEC.

In our work on content rights protection and conditional access, we investigated the advanced conditional access system (CAS) and contributed to the revision of ARIB Standard STD-B61. We also conducted 8K satellite broadcasting experiments at the NHK STRL Open House 2015 using our high-performance scrambler for MMT streams that is compliant with ARIB Standard STD-B61. Experiments demonstrated that the scrambler can process received MMT streams in real time.

In preparation for the SHV test broadcasting starting in 2016, we conducted 8K satellite broadcasting experiments that verified stable transmission and transmission quality of SHV broadcasting. We also developed a dual-polarized receiving antenna, which is capable of separately
1.1 8K Super Hi-Vision format

We made progress with our R&D and standardization activities related to the 8K Super Hi-Vision (SHV) video system.

**High dynamic range video format**

We conducted various experiments on high dynamic range (HDR) imaging and investigated the effects of HDR and the conditions of display luminance. In particular, an experiment examining the influence of the maximum display luminance on video productions showed that producers adjust video to broaden the range of reproduced highlights when the maximum luminance is higher[1]. Other experiments that investigated the minimum perceptible luminance of displays and viewers’ preferred display luminance demonstrated that the minimum perceptible luminance is 0.01 - 0.1 cd/m² in a dim light production environment and that the preferred luminance level for standard dynamic range (SDR) is around 500 cd/m² in a bright home environment[2].

Using these findings, we and the BBC studied an HDR television system and developed the Hybrid Log-Gamma (HLG) solution that is highly compatible with SDR. We jointly proposed this format to the International Telecommunication Union, Radiocommunication Sector (ITU-R) and to the Association of Radio Industries and Businesses (ARIB). This effort led to the establishment of the ARIB Standard STD-B67 in July 2015[3]. We also proposed a revision of the High Efficiency Video Coding (HEVC) standard so that HLG images can be identified in HEVC video streams. Our proposal was adopted in a draft international standard for the HEVC third edition specification.

**Operation of wide gamut colorimetry**

We examined the color rendering index values of LED lighting for wide-color-gamut 4K/8K production. Despite the increasing popularity of LED lighting in recent years, this form of lighting did not have recommendations as to color rendering index values. We conducted subjective evaluation experiments using 8K video captured under various LED lights and found that an average color rendering index (Ra) of higher than 90 and a special color rendering index (R 9) for red of higher than 80 are appropriate for recommended index values[4].

The color-gamut coverage of a display is generally represented by the area-coverage ratio of the display's RGB triangle to the RGB triangle of an imaging system in the standard color space, but different area-coverage ratios are calculated depending on the chromaticity diagram used for calculation (i.e. xy diagram or u’v’ diagram). To address this problem, we investigated the relationship between the area-coverage ratio and volume-coverage ratio in the 3D color space. The results of computer simulations demonstrated that
the area-coverage ratio calculated with the xy diagram has a higher correlation with the volume-coverage ratio. On the basis of these results, we compiled a metric of color space coverage for ultra-high-definition television displays into ARIB Technical Report TR-B36(5).

### Interfaces

We submitted a proposal for an ultrahigh-definition signal/data interface (U-SDI) compliant with ARIB Standard STD-B58 to ITU-R. Our proposal was adopted in Part 2 of ITU-R Recommendation BT.2077 in June 2015, to which wavelength division multiplexing was later added in October(6). The Society of Motion Picture and Television Engineers (SMPTE) also established ST 2036-4 in July 2015(7).

We proposed to ARIB a data structure and multiplexing method for enabling the 4K/8K signal interface to transmit a timecode (TC) supporting up to a 60-Hz frame frequency together with video and audio signals. Our proposal led to the establishment of ARIB Standard STD-B68 in December 2015(8).

The 4K and 8K systems support frame frequencies of up to 120 Hz, but until now, there hasn’t been a TC that supports 120 Hz nor interface for transmitting it. No standards have been defined for them, either. We therefore devised a TC and a transmission interface that support a frame frequency in excess of 60 Hz and maintains compatibility with conventional TC standards. We also prototyped a transmitter and receiver for this TC. These efforts contributed to the standardization activities at SMPTE.

### Video production

With the aim of developing a production switcher for full-featured SHV program production, we developed a blanking switcher as one of its components.

Full-featured SHV includes a 120-Hz frame frequency and wide color gamut. We produced content for making evaluations of these features and showed them at the NHK STRL Open House. We also captured video materials with our 8K full-resolution camera to help the ARIB Test Sequence working group produce ultra-high-definition/wide-color-gamut standard test sequences. In addition, we proposed to ARIB color bar signals including minute patterns to distinguish the 4K and 8K resolutions. Our proposal led to the establishment of ARIB Standard STD-B66 in July 2015(9).

[References]


## 1.2 Cameras

We are researching imaging systems and sensors for practical 8K Super Hi-Vision (SHV) cameras.

### 8K full-resolution single-chip color imaging system

Our goal is to make a practical camera for shooting full-specification SHV video. This year, we made progress on 8K single-chip color imaging systems that are both compact and full resolution.

A full-specification 8K video image contains more than 33 megapixels for each of the red, blue and green channels. In FY 2012, we developed the world’s first 133-megapixel single-chip color image sensor that operates at a 60-Hz frame frequency and achieves full resolution. In FY 2015, we prototyped an 8K full-resolution single-chip color imaging system(10) using this sensor. This is the first single-chip imaging system that captures and displays the full-resolution 8K images.

The prototyped system consists of a camera head (Figure 1) and a camera control unit (CCU). The camera head weighs only 10 kg (excluding the lens weight), about one-fifth that of the previous full-resolution camera. It can use commercial lenses that support 35-mm full frame. The 100-Gbps signal output from the camera head is transmitted to the CCU over a single optical broadcasting camera cable by using our compact, high-speed wavelength division multiplexing transceiver. The CCU performs signal processing such as fixed-pattern noise reduction, gain control, and gamma correction and outputs 8K video signals using a U-SDI optical interface compliant with international standards. We conducted imaging experiments using this system and demonstrated that it achieves the same or higher resolution and sensitivity characteristics compared with the three-chip full-resolution camera that we prototyped in FY 2010.

### Full-featured 8K image sensor

We prototyped a full-featured SHV image sensor (120 Hz, 33 megapixels) in FY2014(11). This year, we improved the performance of the image sensor in terms of its image lag and streaking characteristics (“streaking” is a horizontal linear noise generated when capturing an object with high brightness). The amount of the image lag was reduced to below the
measurement limit by improving the transfer route of electric charges in each pixel from the circuit for accumulating electric charges to the circuit for reading signals. Streaking was reduced to about 1/20th that of previous devices by improving the power wiring layout on the sensor. These performance improvements led to the development of a practical full-specification SHV image sensor. An 8K camera incorporating this image sensor was used for production of programs such as the NHK Kouhaku year-end music show.

### Back-illuminated pixel structure 8K image sensor

We made progress in our research on a SHV image sensor with a back-illuminated pixel structure. In FY 2014, we designed an evaluation image sensor with this structure that had 33-megapixels and operated at 240 Hz. In FY 2015, we fabricated this image sensor (Figure 2) and conducted experiments on it.

The back-illuminated structure makes more efficient use of light to increase the sensitivity than a front-illuminated one.

The sensor also has separately produced pixel- and circuit-units, that are arranged in a three-dimensional stacked structure. For the pixel unit, we used a semiconductor process having a 45-nm design rule. The pixel size was 1.1 μm, and the effective pixel area was about 9.7 mm diagonal. For the circuit unit, we used a semiconductor process having a 65-nm design rule. To convert analog signals into digital ones, we developed a three-stage cyclic A/D conversion circuit with a bit depth of 12 bits and capable of pipeline operation. This reduced the A/D conversion time to 0.92 μs, half that of conventional designs, and realized a high frame rate operation. The pixel unit and circuit unit were directly connected by the semiconductor substrate with wiring having a small pitch (4.4 μm).

Imaging experiments using the test image sensor showed that it had a sensitivity of 0.55 V/lux-s, 5,700 saturated electrons, random noise of 3.6 electrons (converted input value for a quadrupled gain) and power consumption of 3.0 W.(3)

We cooperated with Shizuoka University in developing the full-specification SHV sensor and the back-illuminated 8K sensor.

### Displays

We have made progress in our development of various displays that can handle 8K Super Hi-Vision (SHV) video and continued with our research on large, sheet-type displays.

#### Direct-view 8K displays

In parallel with research on the HDR video format (See 1.1), we developed an HDR 8K liquid crystal display (LCD) in collaboration with Sharp Corporation.(1) By using a highly efficient backlight system and driving technology that controls luminance for each area of the image, this HDR 8K LCD has four times the maximum luminance and 100 times the contrast ratio of previous 8K displays (both actual measurements).

We also developed compact LCD monitors for the purpose of adjusting and monitoring video in 8K program production. One of them is an 8K monitor supporting a 120-Hz frame frequency in anticipation of future introduction of full-featured 8K. This monitor was developed in cooperation with Japan Display Inc. It is 17.3 inch diagonal meaning that it can be mounted on an Outside Broadcast (OB)-van rack and uses a U-SDI as the input interface. The other is the world’s smallest 8K LCD monitor (9.6 inch diagonal) that can be used as a viewfinder in cameras. We fabricated this monitor in cooperation with Ortus Technology Co., Ltd.(2). Its pixels are in a Bayer pattern to compensate for the reduction in the pixel aperture due to the compact size. It uses an input interface composed of eight dual-green 3G-SDIs to enable direct display of dual-green signals without.

![HDR 8K LCD](image1.png)

![17.3-inch diagonal 8K monitor](image2.png)
interpolation.

**SHV sheet-type display technologies**

We are researching large, lightweight, and flexible sheet-type displays that can be rolled up and used in the home for showing SHV. In FY 2015, we studied elemental technologies for such displays, including organic display materials and devices, and thin-film transistors (TFTs) for driving active-matrix displays.

We are researching new organic device structures and materials that extend the operating/storage lifetime and reduce the power consumption of flexible organic light-emitting diode (OLED) displays. The greatest challenge in applying OLEDs to flexible displays is deterioration due to oxygen and moisture in the atmosphere. To address this issue, we are researching a long-lasting OLED with an inverted structure that uses only atmospherically inert materials. In FY 2015, we developed materials that have high light-emitting quantum efficiency of about 75% and a long enough lifetime even when it is on continuously emission[10]. We also prototyped a passive-matrix flexible display (5-inch diagonal, 160x120 pixels) incorporating inverted OLEDs and evaluated its lifetime. The display was sealed with a low gas-barrier film (water vapor transmission rate (WVTR) = 3×10^{-4} g/m²/day; a large display that can easily be produced at low cost in this way). The OLED display with a conventional device structure failed to display after about two weeks of storage. In contrast, the inverted OLED display continued to show moving images after six months with little degradation in luminance[3]. We also found that inverted OLEDs with a low driving voltage can be achieved using ITZO as an electron injection layer. A display fabrication process can be simplified by simultaneous formation of the ITZO channel layer in the TFTs and the ITZO electron injection layer in the inverted OLEDs. We prototyped an 8-inch VGA flexible display (640x480 pixels) using these technologies and demonstrated its capability of displaying video[2] (Figure 4).

**1.4 Recording systems**

We worked to improve the quality of recorded pictures and the performance of the solid state memory package and developed an 8K Super Hi-Vision (SHV) compression recorder that can record video in 4:4:4 without chroma subsampling at a 120-Hz frame frequency[11](Figure 1).

To improve the quality of the recorded pictures, we developed a compression signal processing board capable of real-time processing of SHV 4:4:4 images at a 120-Hz frame frequency. The real time processing is realized by use of double number of high-mobility oxide semiconductor materials for large SHV displays. A TFT for driving SHV displays with a large number of pixels needs low parasitic capacitance and a short channel length. As a way of satisfying these needs, we are researching a back-channel etched TFT, in which electrodes are formed and processed directly on the semiconductor. In FY 2015, we developed a process to fabricate a TFT using ITZO (In-Sn (Tin)-Zn-O) oxide semiconductor material on a plastic substrate. This enabled fabrication of a back-channel etched TFT with a mobility of 31 cm²/Vs, which is three times as high as that of a TFT using the conventional material, IGZO (In-Ga-Zn-O). We also found that inverted OLEDs with a low driving voltage can be achieved using ITZO as an electron injection layer. A display fabrication process can be simplified by simultaneous formation of the ITZO channel layer in the TFTs and the ITZO electron injection layer in the inverted OLEDs. We prototyped an 8-inch VGA flexible display (640x480 pixels) using these technologies and demonstrated its capability of displaying video[2] (Figure 4).

[References]

(1) NHK Press Release: “World’s First 85V 8K LCD with HDR” (Sep. 3, 2015)
the conversion coefficient is a real number, however, the mapping and remapping process deteriorated the signal quality. We conducted simulations on compression on SHV video by using YCoCg color mapping that requires only simple bit manipulations. The results demonstrated that adjusting the conversion coefficient to the image reduced the deterioration in quality and improved the peak signal to noise ratio (PSNR) by up to 2 dB.

We increased the speed of the memory package by upgrading the recording control board. This board parallelizes the compressed data transmitted from the system control board and writes it in the SSD. We found that the narrow bandwidth of the data transmission circuit limited the recording speed. To address this problem, we widened the bandwidth of the transmission circuit in the recording control board. This increased the write and read speeds to in excess of 24 Gbps. We also modified the memory package casing to improve the durability of the removable connectors and thermal resistance. This increased the allowable number of insertions and removals and the reliability of the package.

[References]

1.5 Sound systems providing a strong sense of presence

We are researching a 22.2 multichannel sound (22.2 ch sound) system for 8K Super Hi-Vision (SHV).

- **SHV sound production system**

  We are studying technologies to produce high-quality 22.2 ch sound more easily and efficiently. For sound pickup, we developed a single-unit microphone with directivity control for its shotgun microphone array and devised a robust control for sensitivity errors\(^\text{[5]}\). In response to the establishment of standards for 22.2 ch sound loudness measurements by the International Telecommunication Union, Radiocommunication Sector (ITU-R)\(^\text{(2)}\) and the Association of Radio Industries and Businesses (ARIB), we upgraded our 22.2 ch sound loudness meter to make it compliant with the ITU-R Recommendation. We also developed a preprocessor (software) that generates 22.2 ch sound materials by upmixing stereo or 5.1 ch sound materials. In addition, we developed a signal processing technology for extending the reverberation time while keeping the features of captured reverberation sound, and improved the functionality of the reverberator in use at the Broadcast Center\(^\text{(3)}\).

- **22.2 ch audio coding equipment**

  We developed a 22.2 ch audio encoder/decoder using MPEG-4 AAC as the audio component of an SHV encoder/decoder (Figure 1) and used it in 8K satellite broadcasting experiments. The equipment supports a transmission bitrate of 1.4 Mbps for 22.2 ch. The results of an objective evaluation demonstrated that it has sufficient sound quality for broadcasting \(^\text{(4)}\). We incorporated a downmixing function into the decoder.\(^\text{(5)}\) We also incorporated dialogue control function\(^\text{(6)}\) and user interface by which we experimentally verified the dialogue enhancement function.

- **Sound reproduction system integrated in flat panel display for home use**

  For easy reproduction of 22.2 ch sound at home, we are researching binaural reproduction using a loudspeaker frame integrated with a flat panel display (FPD). In FY 2015, we made a new design that minimizes the control gain as a way of making the signal processing robust against the motion of the viewer’s head when they are watching the display in typical circumstances. We confirmed its effectiveness through
computer simulations. This research was conducted in cooperation with Keio University. We also conducted subjective evaluations of the spatial impression of sound reproduced by the binaural method through the loudspeaker frame and demonstrated that the quality was high enough as a virtual reproduction of 22.2 ch sound(7). In cooperation with manufacturers, we developed a loudspeaker frame with a binaural processing capability that can be attached to commercial flat panel displays. We are studying technology to discriminate the directions of different sounds transmitted to both ears in the binaural reproduction process. In FY 2015, we conducted numerical simulations on the sound transmission characteristics by using different heights of pinna(8). We also conducted experiments on sound direction recognition using sound sources produced by a pinna model wherein the pinna height was varied over a large range. The results showed that sounds coming from the front and back could be distinguished more easily when using this model(9).

■ Standardization

We devised coefficients for calculating the loudness of multichannel sound (including 22.2 ch sound) and experimentally verified them. These efforts led to the revision of the related ITU-R Recommendation(10) as well as ARIB’s loudness operation guidelines(10).

We participated in ITU-R’s standardization activities of sound metadata and audio file formats of 22.2 ch sound and other advanced sound systems. We also contributed to a Preliminary Draft New Recommendation on the order of sound systems and channels when multiple sound systems are used when exchanging programs between broadcast stations.

■ “Ultra-reality” meter

We are studying how to objectively evaluate otherwise subjective factors such as the sense of presence and emotional effect of sound systems. In FY 2015, we prototyped a meter that predicts acoustic impressions from acoustic feature values. This research was supported by the National Institute of Information and Communications Technology (NICT) as part of a project titled “R&D on Ultra-Realistic Communication Technology with Innovative 3D Video technology.”

[References]


1.6 Video coding

We are researching video compression techniques for 8K Super Hi-Vision (SHV) in preparation for the test broadcasting in 2016 and future broadcasting services using various channels.

■ 8K HEVC codec system

We previously developed an SHV video encoder and decoder that conform to the MPEG-H High Efficiency Video Coding (HEVC)/H.265 standard. Using this equipment, we conducted the world’s first 8K broadcasting satellite transmission experiment(6) at the NHK STRL Open House 2015 (Figure 1). The experiment demonstrated that the equipment could compress video and audio to 85 Mbps and 1.4 Mbps, respectively, and that it can be used for broadcasting SHV via satellite without significantly deteriorating its quality(7).

We developed an 8K HEVC video decoding LSI that is compliant with the ARIB STD-B32 standard for SHV.
broadcasting and capable of decoding compressed video streams in real time. We also developed video decoding evaluation equipment using this LSI. This development was conducted in cooperation with Socionext Inc.

We investigated the required bit rates on 8K/120-Hz video for broadcasting. In accordance with the domestic standards for SHV broadcasting, we conducted a verification using temporal scalable coding that can partially decode 60-Hz video frames from compressed 120-Hz video streams. We derived the relationship between inter-frame correlation and bit rate assignment for each scalable layer from preliminary experiments using 2K video. We then conducted experiments on 8K/120-Hz video with similar conditions and confirmed that high image quality could be obtained through informal subjective evaluations.

### HDR video coding and standardization

We conducted coding experiments on high dynamic range (HDR) video signals and verified the coding efficiencies of different video formats.

The video formats included the Hybrid Log-Gamma (HLG) format that was jointly developed by NHK and the BBC and is specified in the ARIB STD-B67 standard, and the perceptual quantizer (PQ) format of the SMPTE ST 2084 standard. We compared the image qualities of the decoded video signals of these formats for various bit rates. In particular, the objective evaluations demonstrated that the required bit rate of the HLG and PQ formats did not increase compared with that of the conventional standard dynamic range (SDR). The image qualities of the decoded video signals of each format both displayed on an SDR display proved that the HLG format was compatible with the SDR. We reported these results to the working group on video coding systems at ARIB.

To enable broadcasting of ultra-high-definition HDR video, we standardized identifiers for HDR content within MPEG-H HEVC/H.265. We also added identifiers to the domestic ARIB standard for video coding formats of ultra-high-definition television broadcasting and revised the technical report.

### Next-generation video coding

We began research on next-generation video coding targeting services including future terrestrial SHV broadcasting. Conventional video coding frameworks employed a block-based coding approach that partitions the input video signals into blocks, which are successively applied a combination of prediction, transformation and quantization techniques. To improve coding efficiency, we developed a framework that uses super-resolution reconstruction techniques (Figure 2). This framework significantly reduces the amount of information by sub-sampling input video blocks anticipating information recovery by super-resolution techniques. In combination with prediction, transformation and quantization techniques, the improvement of coding efficiency can be expected. Note that the sub-sampling is conducted considering the performance of super-resolution reconstruction in decoders. The encoded sub-sampled signals are super-resolved to the original resolution in decoders.

In FY 2015, we developed technologies to improve the orthogonal transforms and spatial prediction (intra prediction). For high-definition videos including SHV, it is known that the overall quality can be improved by partitioning a block into sub-blocks with various sizes depending on smooth/textured areas upon encoding. On the other hand, the use of large blocks increases the amount of processing and hampers the feasibility of a hardware implementation. To address this problem, we developed a transform technique that decomposes large-sized transforms into multiple smaller bases. The new transform technique improves coding efficiency by up to 7% compared to conventional ones(23). For the quantized transformed coefficients, we devised a coefficient transmission technology focusing on signal variations of coefficient sequences(24) and a waveform reconstruction method for applying offsets according to the signal characteristics. For the intra prediction process, we developed a way of determining the prediction mode depending on the signal features of the surrounding reference samples and confirmed that it improved image quality.

### Reconstructive video coding

We continued our research on video coding that uses super-resolution techniques(25) (26). We previously developed real-time inter-layer prediction processors that enable scalable transmission of multiple resolution videos with the aid of super-resolution techniques. The processors were installed and tested with parameter optimization functionality based on new criteria that is capable of measuring errors between the original and reconstructed images and image features as well. We developed a lossless compression method for super-resolution parameters based on temporal prediction and arithmetic coding. We developed an IP transmission device that delivers the compressed parameters and data synchronization bits and verified its real-time operation. This research was performed under the auspices of the Ministry of Internal Affairs and Communications, Japan through its program titled "Research and Development of Technology Encouraging Effective Utilization of Frequency for Ultra High Definition Satellite and Terrestrial Broadcasting System".

We are also researching video format conversion technologies using super-resolution techniques(27) (28). In FY 2015, we developed a frame-rate conversion technique which is extended the spatial super-resolution technique into the temporal direction(29). The developed technique utilizes the linear-filtering frame interpolation method by using spatio-temporal contrast compensation considering the eye-tracking integration effect and spatio-temporal contrast sensitivity characteristics of the human visual system. This technique could be reduced an image degradation in which the moving area appears like multiple images.

[References]

6. Y. Matsuo, S. Iwamura, K. Iguchi and S. Sakaida: “Real-time sequence(26) and a waveform reconstruction method for applying offsets according to the signal characteristics. For the intra prediction process, we developed a way of determining the prediction mode depending on the signal features of the surrounding reference samples and confirmed that it improved image quality.
1.7 Media transport technologies

We are researching media transport technologies for 8K Super Hi-Vision (SHV) broadcasting and hybrid services that take advantage of broadcasting and telecommunications.

■ SHV broadcasting system

MPEG Media Transport (MMT) can be used for both broadcasting and broadband networks. It has been adopted as the media transport scheme for the SHV satellite broadcasting and specified in ARIB Standard (ARIB STD-B60). We developed an encoder for 8K video and 22.2 multichannel audio, a multiplexing device, a transmitter/receiver for satellite broadcasting, a demultiplexing device, and a video and audio decoder that are compliant with this Standard and conducted experiments using an actual satellite. The experiment demonstrated the feasibility of live SHV satellite broadcasting. We showed seamless switching between content transmitted by broadcasting and content transmitted over the Internet. This switching enables presentation of content suited to individual viewers. We also showed a hybrid service (Figure 1) that presents different pieces of content in synchronization with each other, although they were transmitted in different paths. This research was performed under the auspices of a program, titled “Research and Development of Technology Encouraging Effective Utilization of Frequency for Ultra High Definition Satellite and Terrestrial Broadcasting System”, of the Ministry of Internal Affairs and Communications, Japan.

Aiming for harmonization of satellite broadcasting and telecommunications, we proposed a protocol for starting and ending sessions that transmit video and audio to individual receivers. We also proposed an appropriate operation mode of error correction method in the application layer for maintaining transmission quality. These proposals were verified in an experiment on a transmitter and receiver developed on the basis of our proposals.

■ International standardization related to MMT-based broadcasting

The International Telecommunication Union, Radiocommunication Sector (ITU-R) issued a new Recommendation on the MMT-based broadcasting system (BT.2074). The ISO/IEC (International Organization for Standardization and the International Electrotechnical Commission) issued the ISO/IEC TR 23008-13 “MMT implementation guidelines” that specifies the configuration of a broadcasting system using MMT. In addition, the Advanced Television Systems Committee (ATSC), an organization for standardizing next-generation terrestrial broadcasting systems in the U.S, issued a Candidate Standard on “Signalling, Delivery, Synchronization and Error Protection,” which includes MMT.

[References]


(4) Recommendation ITU-R BT.2074-0, “Service configuration, media transport protocol, and signalling information for MMT-based broadcasting systems”

### 1.8 Advanced conditional access system

We are researching an advanced conditional access system (CAS) that provides rights protection and conditional access to 8K Super Hi-Vision content.

#### Advanced conditional access system technology

The advanced CAS technology uses a secure scrambling scheme and supports a CAS module software update function to assure continuous provision and improvement of security.

Following the “Technical conditions for ultra-high-definition television system” report issued by the Information and Communications Council in March 2014, we participated in standardization work at ARIB, which later issued a standard, “Conditional Access System (Second Generation) and CAS Program Download System Specifications for Digital Broadcasting” (ARIB STD-B61), for ultra-high-definition television in July 2014.

The advanced CAS can transmit viewing license information through a communication or broadcasting channel, thereby enabling the receiver to obtain the contract information through an HTML5 browser. We examined application programming interfaces (APIs) for this function and worked on standardization.

We also conducted 8K satellite broadcasting experiments at the NHK STRL Open House 2015 using our high-performance scrambler for MMT streams that is compliant with ARIB STD-B61. Experiments demonstrated that the scrambler can process received MMT streams of about 90 Mbps (actual value) in real time with a delay of less than 1 msec\(^{(1)}\).

[References]

### 1.9 Satellite broadcasting technology

To promote 8K Super Hi-Vision (SHV), we are improving the practicality and performance of the 12-GHz-band satellite broadcasting and researching next-generation satellite broadcasting systems in the 21-GHz band.

#### Advanced transmission system for satellite broadcasting

We presented the world’s first 8K satellite broadcasting in the 12-GHz band at the Open House 2015; the demonstration showed that stable 8K transmissions could be received by a parabolic antenna 45 cm in diameter.

With support from the Broadcasting Satellite System Corporation (B-SAT), we conducted satellite transmission experiments using the BSAT-3b satellite in which we examined all possible combinations of the modulation schemes and code rates specified by the ARIB STD-B44 standard. We found that in comparison with a vehicle-mounted station (tested by ARIB in 2014), a large earth station can reduce the required C/N by 0.4 dB from 12.6 dB when 16APSK (amplitude phase shift keying) modulation is used with a code rate of 7/9.

We submitted a Preliminary Draft New Recommendation on Japan’s satellite transmission schemes to the International Telecommunication Union, Radiocommunication Sector (ITU-R). We also provided the results of our satellite transmission experiments for the draft ITU-R report.

To improve the performance of satellite transmission schemes, we researched QAM (quadrature amplitude modulation) multi-level coded modulation using set partitioning, cross polarization elimination technology, and a technique to reduce distortion caused by the satellite transponder.

For QAM multi-level coded modulation using set partitioning, we proposed a method to improve performance by applying set partitioning, which increases the minimum Euclidean distance for each bit constituting a symbol, to 32QAM and optimizing the error correction coding for each bit. Computer simulations showed that the required C/N for additive white Gaussian noise was about 0.3 dB better than that of Europe’s next-generation satellite transmission scheme (DVB-S2X) when the code rate for the entire signal is 4/5\(^{(1)}\) (Figure 1).

Regarding the interference elimination technology, we improved reception characteristics of right- and left-hand circularly polarized waves in 12-GHz-band satellite broadcasting. Computer simulations on interference elimination of cross polarization indicated that the required C/N improved by approximately 0.4 dB with 32APSK (code rate of 3/4) at the satellite loop back.

To improve transmission performance for the 16APSK at the satellite loop back, we researched technologies to reduce distortion caused by the satellite transponder. We prototyped a high power solid-state amplifier that has higher linearity than the current traveling wave tube amplifier in order to improve non-linear characteristics of on-board amplifiers. It uses gallium nitride, which has high power efficiency. Circuit design simulations showed that it can achieve a gain in excess of 7 dB and an output power in excess of 100 W. This research was funded by the Ministry of Internal Affairs and Communications, Japan through its program titled “Research and Development of Technology Encouraging Effective Utilization of Frequency for Ultra High Definition Satellite and Terrestrial Broadcasting System”.

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![Figure 1. Transmission performance of set partitioning 32QAM](image-url)
Next-generation satellite broadcasting systems

For the next generation of satellite broadcasting, we developed an on-board output filter and a dual-polarized receiving antenna that can receive both right- and left-hand circularly polarized waves. We also designed and prototyped a 21-GHz array-fed shaped-reflector antenna and conducted wide-band transmission tests.

The next-generation broadcasting satellite will feature left-hand circularly polarized waves in the 12-GHz band for SHV broadcasting and a wide passband to accommodate the increased symbol rate. We prototyped a fourth-order elliptic filter that has a wider passband than that of conventional ones and verified its performance. Simulations using design values showed that preventing amplitude deterioration in the passband edges improved the output by 0.2 dB and that reducing the group delay deviation in the phase improved the required C/N by 0.1 dB.

We prototyped an offset parabolic antenna that uses a four-element micro strip array antenna as a feeder. The antenna can receive both right- and left-hand circularly polarized waves for 12-GHz satellite broadcasting and has a cross-polarization discrimination ability of over 25 dB. We also prototyped and evaluated a satellite converter that supports left-hand circularly polarized waves at the intermediate frequencies of BS and CS broadcasting. The results showed that the local oscillator output leakage was -55 dBm or less and the image rejection ratio was 55 dB or more. The results of this evaluation were incorporated in a revision of the related ARIB standard.

We researched the effect of using reflector shaping technology on a 21-GHz-band array-fed reflector antenna. We calculated various radiation patterns by changing the number of elements and the diameter of the reflecting mirror. The results demonstrated that reflector shaping reduces side lobes, equalizes the excitation power of array elements, and enables radiation patterns to cover the whole country uniformly even if the number of elements is decreased. The radiation patterns can be changed by controlling the phase.

We prototyped a 21-GHz-band array-fed shaped-reflector antenna (array-fed IRA). The main reflector of the array-fed IRA was used an offset shaped-reflector made from carbon fiber materials fabricated in FY2011. We prototyped a feed array and a sub-reflector in this fiscal year. We conducted experiments showing that a radiation pattern covering the whole country could be uniformly formed by arranging 31 elements of equal amplitude and phase in the feed array while radiation patterns with stronger beams could be formed by controlling the phase. In addition, side lobes were reduced compared with the radiation patterns formed with a parabolic reflector.

For the 21-GHz-band satellite broadcasting system, we prototyped a modulator and demodulator for a 300-MHz-class bandwidth and an output filter that suppresses unnecessary emissions into radio astronomy bands. We conducted transmission experiments on these devices in combination with an array-fed reflector antenna and found that they could transmit SHV signals with only a little degradation (0.1 to 0.2 dB) in the CN ratio, which was caused by the spatial synthesis of the array element outputs of the antenna. We also found that a power increase of about 5 dB can be achieved by controlling the phase of the array elements. Moreover, interleaving for about one second helped to transmit video without interruption even during beam switching. This research was funded by the Ministry of Internal Affairs and Communications, Japan through its program titled “Research and development of efficient use of frequency resource for next-generation satellite broadcasting system”.

We studied thermal transportation methods for antennas with fewer array elements and a high-power traveling wave tube (TWT). This research was conducted in cooperation with the Japan Aerospace Exploration Agency (JAXA).

1.10 Terrestrial transmission technology

For terrestrial broadcasting of Super Hi-Vision (SHV), we are researching a next-generation terrestrial transmission system, transmission network, and transmission technology for mobile reception.

Proposed specifications

We are in the process of establishing proposed specifications (Table 1) for the purpose of migrating the current terrestrial broadcasting services to the next-generation system. In FY 2015, we considered detailed specifications on hierarchical multiplexing, etc., conducted computer simulations on designs conforming to the specifications, and built the hardware corresponding to a part of the specifications.

The proposed specifications incorporate the latest technologies while inheriting the advantages of the current standard ISDB-T (Integrated Services Digital Broadcasting - Terrestrial). The number of symbols per channel has been increased from 13 to 35 so that the signals for fixed reception and those for mobile reception can be flexibly combined. Also, a new parameter for reducing the guard band and guard interval that do not contribute to information transmission has been added to increase frequency usage efficiency. The forward error correction uses low-density parity-check (LDPC) codes and BCH codes with three LDPC code lengths. Spatially coupled low-density parity-check (SC-LDPC) codes, which can generate long codes efficiently and perform well in decoding, are used for the longest code (approximately 260 kbit)[8]. For block coding with long codes, we studied a method for efficiently

<table>
<thead>
<tr>
<th>Table 1. Segment parameters of proposed specifications</th>
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<tbody>
<tr>
<td><strong>Mode</strong></td>
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<tr>
<td><strong>FFT size</strong></td>
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<tr>
<td><strong>Bandwidth (kHz)</strong></td>
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<tr>
<td><strong>Number of carriers</strong></td>
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<tr>
<td><strong>Carrier modulation</strong></td>
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<tr>
<td><strong>Effective symbol length (μs)</strong></td>
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<tr>
<td><strong>Number of symbols per frame (Gt)</strong></td>
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<tr>
<td><strong>Gt ratio</strong></td>
</tr>
<tr>
<td><strong>FFT sample rate (MHz)</strong></td>
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transmitting pointer information to find the beginnings of the codes and synchronize them.35

■ Transmission experiments in urban areas

In April 2015, we set up an experimental SHV station (31 ch, 10 W output) on the rooftop of our laboratory in order to evaluate the propagation characteristics of the dual-polarized multiple-input multiple-output (MIMO) ultra-multilevel orthogonal frequency division multiplexing (OFDM) system in urban areas where buildings cause multi-path effects. We conducted an experiment at the Open House 2015, in which a SHV program compressed to 77.7 Mbps was transmitted from the experimental station and received 8 km away at the NHK Broadcast Center in Shibuya.

We also conducted reception experiments in Setagaya Ward that evaluated four propagation characteristics of dual-polarized MIMO transmissions, that is, horizontally polarized reception and signal leakage of horizontally polarized transmissions in vertically polarized reception as well as vertically polarized reception and signal leakage of vertically polarized transmissions in horizontally polarized reception. These characteristics were then analyzed through computer simulations.

■ Coding SFN

We are researching technologies for a single frequency network (SFN) that can use frequencies efficiently. In FY 2015, we conducted experiments at two experimental stations in Hitoyoshi City, Kumamoto Prefecture to compare the performance of a coding SFN with that of a conventional SFN. The experiments used the Space Time Coding (STC) SFN device that we developed in FY 2014. The results showed that the coding SFN has as much as a 3 dB lower required reception power 36 and a larger MIMO channel capacity compared with the conventional SFN (Figure 1). We proposed to the International Telecommunication Union, Radiocommunication Sector (ITU-R) that the experiment results be reflected in the UHDTV field experiment results report.37 This research is being performed under the auspices of the Ministry of Internal Affairs and Communications, Japan as part of its program titled “Research and Development of Technology Encouraging Effective Utilization of Frequency for Ultra High Definition Satellite and Terrestrial Broadcasting System”.

■ Transmission technology for mobile reception

We are researching a space division multiplexing (SDM) MIMO-OFDM transmission technology to provide high-quality images comparable to those of Hi-Vision for the next-generation terrestrial broadcasting mobile reception services. In FY 2015, we conducted field experiments to compare the mobile reception area of the current terrestrial broadcasting (Hi-Vision) and that of the next-generation terrestrial broadcasting.38 The next-generation terrestrial broadcasts had the same characteristics as those current terrestrial broadcasts being received with four reception antennas when the 16QAM (quadrature amplitude modulation) scheme with a code rate of 1/2 was applied (Figure 2).

■ Collaboration with overseas organizations

We participated in activities at the Advanced Television Systems Committee (ATSC), an organization for standardizing next-generation terrestrial digital broadcasting in the U.S., and contributed to the development of specifications for dual-polarized MIMO and higher order modulation. We also exchanged technologies related to next-generation terrestrial broadcasting with South Korea’s Electronics and Telecommunications Research Institute (ETRI). In addition, we began discussions with a Brazilian TV broadcaster, TV Globo, on the planned 8K terrestrial transmission experiments of the Rio de Janeiro Olympics.

[References]
1.11 Wireless transmission technology for program contributions (FPU)

We are researching field pick-up units (FPUs) that can transmit 8K Super Hi-Vision (SHV) signals for program contributions. In FY 2015, we studied a 42-GHz-band FPU, a microwave-band FPU, and a 1.2-GHz/2.3GHz-band FPU for mobile transmissions.

■ 42-GHz-band FPU

We researched a 42-GHz-band FPU with the aim of achieving a 400-Mbps-class transmission rate. We modified the sub-carrier modulation scheme of our 2×2 multiple-input multiple-output (MIMO) - orthogonal frequency division multiplexing (OFDM) modulator and demodulator units with a bandwidth of 54.4 MHz from 16QAM (quadrature amplitude modulation) to 32QAM. We demonstrated that the FPU is capable of 200-Mbps transmission through radio frequency (RF) equipment which we prototyped in FY 2014 (Figure 1). In FY2015, we also prototyped modulator and demodulator units that support 109-MHz bandwidth of OFDM signals to further increase the transmission rate to 400 Mbps.

To explore radio wave propagation characteristics in the 42-GHz band, which is susceptible to rain attenuation, we conducted long-term radio wave propagation experiments between the NHK Broadcasting Center and our laboratory (Figure 2). Using the acquired experimental data on received power and rainfall intensity, we then investigated the influence of rainfall on the transmission characteristics within the band.

■ Microwave-band higher-order modulation OFDM-FPU

We made progress in our research on a 6/7-GHz-band FPU with a 200-Mbps-class transmission rate with the aim of achieving long-distance transmission of SHV signals. We conducted long-haul transmission experiments using the modulator and demodulator units and RF units that we prototyped in FY2014 using dual-polarized MIMO technology and OFDM with higher-order modulation scheme. The experiments included measuring the transmission characteristics and sending SHV signals over a distance of 59 km. The results showed that the prototype FPU worked as designed, although the transmission characteristics deteriorated by around 1 dB compared with those in laboratory experiments (Figure 3). We also confirmed 200-Mbps-class transmissions of SHV signals, demonstrating long-distance wireless transmission of SHV signals(2).

We also made progress on device development. In FY 2015, we prototyped a modulator and demodulator units whose transmission parameters such as the OFDM symbol length and pilot signal configuration are tolerant to instantaneous variations in the channel environment.

■ 1.2-GHz/2.3-GHz-band FPU for mobile transmission

We are researching a wireless transmission system that would enable mobile relay broadcasting of SHV signals. In FY 2015, we continued with our study on the MIMO eigenmode transmission scheme(3) that adaptively controls the transmission beam, modulation scheme, and transmission power by using a bidirectional communication and built a prototype. We demonstrated that it is possible to suppress the increase in the required signal-to-noise ratio (SNR) to 0.5 dB or less when the precoding matrix to be fed back as control information is quantized in 3 bits, compared with the case of precoding matrix fed back without quantization(4). We also found that if the amount of feedback information is reduced to 1/8th in sub-carrier units, the deterioration in required SNR is only around 1 dB even in a channel environment with a large delay spread. On the basis of these results, we designed a signal format for the prototype equipment.

We also studied a way of controlling the code rate of error...
correction coding adaptively according to the varying channel quality. We investigated an error correction coding method that uses Reed-Solomon code (204,188) as an outer code and a turbo code with the mother code rate of 1/3 as an inner code. A variable code rate is possible with bit puncturing, in which a rate matching technology dynamically controls the amount of parity bits according to the channel environment. We also examined an interleaver between the inner and outer encoders for improving the characteristics of concatenated codes. We implemented these techniques in a prototype device and evaluated the MIMO eigenmode transmission scheme and error-correcting capabilities. Part of this research was conducted as a government-commissioned project from the Ministry of Internal Affairs and Communications, titled “R&D on highly efficient frequency usage for the next-generation program contribution transmission.”

1.12 Wired transmission technology

- **Ethernet optical transmission of uncompressed 8K SHV signals**

  We are researching a wired transmission system for uncompressed 8K Super Hi-Vision (SHV) program contributions, which is to be used within a broadcast station for delivering program contributions from one place to another.

  In FY 2015, we developed a U-SDI/Ethernet packet converter (Figure 1) that multiplexes optical signals of the U-SDI (Ultra-high-definition Signal/Data Interface) that are compliant with the ARIB STD-B58 standard into 100 Gigabit Ethernet (100GE) signals for transmission. An uncompressed full-specification 8K signal with a 120-Hz frame frequency and a 4:4:4 sampling structure contains about 144 Gbps of video specification 8K signal with a 120-Hz frame frequency and a (100GE) signals for transmission. An uncompressed full-specification 8K SHV signal is to be used within a broadcast station for delivering uncompressed 8K Super Hi-Vision (SHV) program contributions, which two channels’ worth of 4K video was converted into Ethernet optical transmission of uncompressed 8K SHV signals.

  Part of this research was conducted as a government-commissioned project from the Ministry of Internal Affairs and Communications, titled “R&D on highly efficient frequency usage for the next-generation program contribution transmission.”

![U-SDI/Ethernet packet converter](image)

Figure 1. U-SDI/Ethernet packet converter

- **Cable TV transmission of SHV signals**

  We are promoting the development and standardization of a channel bonding technology to transmit partitioned SHV signals over multiple channels so that SHV programs can be distributed through existing coaxial cable television networks. In FY 2015, we conducted laboratory experiments on an SHV cable TV transmission system that uses MPEG Media Transport (MMT) and Type Length Value (TLV) multiplexing schemes and successfully transmitted 100-Mbps SHV Satellite broadcasting signals through cable TV. We participated in standardization activities at the Japan Cable Television Engineering Association (JCTEA). All the domestic standards for the channel bonding technology have been published. We also provided input to Study Group 9 of the International Telecommunication Union, Telecommunication Standardization Sector (ITU-T) for the purpose developing an international standard consistent with the domestic standards. Our proposal was approved as Recommendations.

- **Baseband optical fiber distribution scheme for FTTH**

  As a way of distributing broadcasts to homes using FTTH (Fiber to the home), we are studying a baseband optical fiber distribution scheme in which the baseband signals of SHV and Hi-Vision broadcasting are multiplexed with 10-Gbps-class baseband signals by using time division multiplexing (TDM) and transmitted over optical fibers. In FY 2015, we evaluated an experimental prototype to determine the conditions for stable wavelength division multiplexing transmission of baseband signals and conventional RF signals. We also examined time-multiplex technology to reduce the load on the receiver when SHV (MMT) and Hi-Vision (MPEG-2 TS) signals are mixed.

![U-SDI/Ethernet packet converter](image)

Figure 1. U-SDI/Ethernet packet converter

**References**


1.13 Domestic standardization

We are engaged in domestic standardization activities related to 4K and 8K ultra-high-definition television satellite broadcasting systems. In 2014, the Ministry of Internal Affairs and Communications promulgated a Ministerial Ordinance and Public Notice (national technical standards), and the Association of Radio Industries and Businesses (ARIB) established a series of technical standards that specify these television systems. Since then, ARIB has worked on revisions of these standards, such as additions and clarifications in accordance with operational guidelines established by the Next Generation Television & Broadcasting Promotion Forum (NexTV-F) (Table 1). In November 2015, the Broadcasting System Subcommittee of the Information and Communications Council’s Information and Communications Technology Sub-Council began a study on the technical conditions of high dynamic range television.

Members of NHK STRL contributed to these standardization efforts on ultra-high-definition television broadcasting by participating as members of the Information and Communications Council working group, committee chairmen of ARIB development sections, and managers and members of ARIB working groups.

<table>
<thead>
<tr>
<th>Domain</th>
<th>ARIB Standard</th>
<th>Major revisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiplexing (MMT/TLV)</td>
<td>STD-B60</td>
<td>Addition and modification of application transmission and descriptors</td>
</tr>
<tr>
<td>Conditional access</td>
<td>STD-B61</td>
<td>Addition of CAS program download and conditional access system that support MMT/TLV multiplexing</td>
</tr>
<tr>
<td>Video coding</td>
<td>STD-B32 Part 1</td>
<td>Addition of HEVC coding for low-resolution video and high dynamic range television</td>
</tr>
<tr>
<td>Audio coding</td>
<td>STD-B32 Part 2</td>
<td>Clarification of seamless switching of audio parameters and MPEG-4 ALS specifications</td>
</tr>
<tr>
<td>Multimedia coding</td>
<td>STD-B62</td>
<td>Addition of HEVC coding for low-resolution video and functions of ARIB TTML</td>
</tr>
<tr>
<td>Receiver</td>
<td>STD-B63</td>
<td>Addition of intermediate frequency supporting left-hand circular satellite polarization, download functionality, decoding of low-layer video during hierarchical transmission, and video processing for high dynamic range</td>
</tr>
</tbody>
</table>
2 Three-dimensional imaging technology

With the goal of developing a new form of broadcasting delivering a strong sense of presence, we are pursuing development of a more natural and viewable three-dimensional television that does not require special glasses. In particular, we are researching integral 3D imaging technologies and devices for displaying 3D images.

In our research on display technologies of the integral 3D method, we are developing elemental technologies to increase the number of pixels and expand the viewing zone. In FY 2015, we prototyped direct-view 3D display equipment that achieves a resolution equivalent to 16K by spatially connecting images with a magnifying optical system that has four 8K liquid crystal panels arrayed in parallel. This equipment can display 3D images that have about 100,000 pixels and an area about four times as large as that possible with the previous one.

The MPEG-Free-viewpoint Television (FTV) ad hoc group started its standardization activities in 2013, and we have been participating in this group. In FY 2015, we attended MPEG meetings and conducted coding experiments on using the High Efficiency Video Coding (HEVC) and Multi-View (MV)-HEVC schemes on integral 3D images.

In our research on capture technologies of the integral 3D method, we are studying technologies to obtain spatial information by using multiple cameras and lens arrays for creating high-quality 3D images. In FY 2015, we developed capture equipment that uses 64 Hi-Vision cameras and a lens array. We also developed a capture technique using two-dimensional arrays of multi-viewpoint cameras that does not require a lens array. Moreover, we researched new video production methods that use these capture technologies and multi-viewpoint robotic cameras.

In FY 2015, we began a study on the system parameters of the integral 3D method. In order to simulate the relation between the display parameters of the integral 3D method and image quality (in terms of the depth reproduction range, resolution, viewing zone), we prototyped stereoscopic 3D display equipment that has 3D models and a high-precision viewpoint tracking function and conducted subjective evaluations that examined image quality in terms of the pixel pitch and depth range. We also began development of a method to express a large space within the narrower depth range, taking advantage of the characteristics of human depth perception.

In our research on 3D display devices, we have been studying electronic holography devices and beam steering devices. For electronic holography, we continued to study spatial light modulators using spin transfer switching (spin-SLM). In FY 2015, we developed a silicon backplane with 2-μm pixel pitch, which has a build-in logic circuit for parallel operation, and an external drive system for the backplane. We also prototyped a 2D spin-SLM whose light modulation element exploits tunnel magneto-resistance on the silicon backplane and evaluated its performance. With the aim of building an integral 3D display that uses beam steering devices instead of a lens array, we studied optical waveguide arrays made of electro-optic materials. Our work in FY 2015 included operation simulations and prototyping of an optical waveguide with a 1D array structure.

2.1 Integral 3D imaging technology

Improvement of integral 3D image quality

We are continuing with our R&D on a 3D television system that offers more natural 3D images to viewers without them having to use special glasses. The integral 3D method can reproduce natural 3D images by using a high-definition display with high-density pixels and a lens array with a large number of micro lenses to reproduce light rays in many directions.

The integral 3D method, which reproduces many light rays into various directions, requires a display with many pixels for displaying elemental images. Previously, one 8K Super Hi-Vision display was used for showing these 3D images, but the quality of the 3D images was rather low.

With the goal of developing a display that can display images of sufficient quality for practical use, in FY 2015, we developed a technology to connect images of four 8K-equivalent, high-definition liquid crystal panels (dual-green type; 9.6 inch diagonal). We also improved the resolution characteristics of the magnifying optical system and developed a technology for reducing luminance irregularities between magnified images. Our efforts led to the development of direct-view 3D image...

Figure 1. Integral 3D image reproduced by the direct-view display equipment using four 8K liquid crystal panels
display equipment able to display 16K-equivalent images. Integral 3D images with elemental images having about 100,000 pixels (420 pixels horizontal × 236 pixels vertical) could be displayed in an area about four times as large as that possible with the previous equipment(1) (Figure 1).

 Coding technologies for integral 3D images

We are researching coding technologies for elemental images used in the integral 3D method. In FY 2014, we began a study on compression efficiency that applied existing video coding techniques to the integral 3D method. In FY 2015, we demonstrated that it is more effective to convert elemental images into multi-viewpoint images and then apply Multi-View (MV)-High Efficiency Video Coding (HEVC) to the multi-viewpoint images than to apply HEVC directly to elemental images(2). This method has higher coding efficiency because it uses an image conversion technology that makes the pitch of the elemental images an integral multiple of the pixels when they are converted into multi-viewpoint images(3). We also participated in standardization activities at the MPEG-FTV ad hoc group.

 Technologies for capturing spatial information

In integral 3D imaging, it is necessary to capture information on the directions and colors of many light rays propagating through the air; this sort of information is called spatial information. We investigated various ways of capturing spatial information using multiple cameras and lens arrays in order to reproduce high-quality integral 3D images.

A single capture device can capture only a limited number of pixels. Since FY 2012, we have been studying equipment that can capture more pixels by using a camera array with multiple cameras arranged close to each other. In FY 2015, we increased the number of Hi-Vision cameras in the camera array to 64 in order to capture more pixels and increased the number of micro lenses in the lens array to around 100,000 (Figure 2). This resulted in a threefold increase in the number of pixels in the 3D images from that of the prototype equipment developed in FY 2014, which had seven Hi-Vision cameras and around 30,000 micro lenses. We also increased the accuracy of the method of synthesizing the images captured by the camera and lens arrays, which improved the quality of the resulting 3D images. In addition, we prototyped compact capture equipment that has two small lens arrays adhering to a Super Hi-Vision image sensor(1). This equipment can capture high-quality images by synthesizing information obtained from each lens array.

In other research, we examined a capture system that does not use a lens array and in which multi-viewpoint cameras are sparsely arranged. This system generates a 3D model of the object from the multi-viewpoint images it captures and converts it into an image equivalent to the one that would be obtained from a system with a lens array. In FY 2015, we developed a method for accurately capturing an area of integral 3D image reproduction by using multi-viewpoint cameras arranged in two dimensions (3). This method adjusts the capture area of the cameras to the reproduction area for the integral 3D images and controls the posture and zoom of the multi-viewpoint cameras to contain the reproduction area within the angle of view. By doing so, horizontal and vertical light rays in the reproduction area of the integral 3D images can be captured within an appropriate angle of view. Generating a 3D model requires the depth to be estimated with stereo cameras. The new method increases the number of stereo camera pairs by arranging multi-viewpoint cameras in two dimensions in a regular hexagon (Figure 3). This improves the accuracy of the depth estimation.

We incorporated these spatial information acquisition technologies in a multi-viewpoint robotic camera capable of cooperative control of the camera array direction. We also developed a new image presentation technique which can switch to the image of the camera that best captures the movements of the subjects such as players and the ball in sport scenes and display it. Part of this research was conducted under contract by the Ministry of Internal Affairs and Communications for its project titled, “R&D on systems for capturing spatial information using multiple image sensors.”

 System parameters of the integral method

We have been studying ways of measuring and improving the quality of 3D images reproduced using the integral method since FY 2012.

The integral method forms 3D images in the air. Theoretically, the method is able to display 3D images that are as natural looking as the actual object. To verify this feature, in FY 2014, we measured the visual response characteristics of persons viewing integral 3D images and evaluated the accuracy of depth discrimination by motion parallax. In FY 2015, we began research aimed at deriving system parameters that could serve as guidelines for designing integral 3D imaging systems. The display parameters that affect the quality of integral 3D images (where quality is expressed in terms of the depth reproduction range resolution, and viewing zone) are the pixel pitch of the display showing the elemental images, the pitch of the micro lenses in the lens array, and the focal length. The values of these parameters need to be varied in order to evaluate the quality, but it is difficult to produce integral display equipment with various parameter values. Therefore, we conducted evaluations by reproducing the states of viewing integral 3D images with a stereoscopic 3D display. This evaluation equipment calculates the light rays reproduced by the integral display from 3D models of objects and simulates integral 3D images viewed from a certain viewpoint. It can also reproduce motion parallax, a feature of the integral method, by using its viewpoint tracking function. In FY 2015, we conducted subjective evaluations using this equipment in which the image quality relative to the depth of the integral 3D images was varied by changing the pixel pitch of the display. The experiments provided us with data on the spatial frequency (theoretical values) and image quality of 3D images(4). We also began development of a method to express a large space...
within the narrower depth range, taking advantage of the characteristics of human depth perception. We plan to use this method to find the minimum bound of the depth range that can keep naturalness of an original scene expression, and use it to determine the system parameters of the integral 3D imaging system that can naturally express a variety of scenes with large depth.

[References]

2.2 Three-dimensional imaging devices

Spatial light modulator driven by spin-transfer switching

We are researching electronic holography with the goal of realizing a spatial imaging form of three-dimensional television that shows natural 3D images. Displaying 3D images in a wide viewing zone requires a spatial light modulator (SLM) having a very small pixel pitch, an extremely large number of pixels, and high driving speed. We are developing a spin-transfer SLM (spin-SLM) for minute pixels less than 1 \( \mu \text{m} \) in size. The spin-SLM can modulate light by using the magneto-optical Kerr effect of the light modulation element. Applying an electric current to this element inverts the magnetization direction of the magnetic materials in the pixel.

We previously developed a tunnel magneto-resistance (TMR) light modulation element\(^{(1)}\) that can operate at a low current as a magnetic material that constitutes a pixel. The TMR light modulation element consists of three layers: a pinned layer, an insulating layer and a light modulation layer. A transparent electrode common to all elements is placed in the upper part of the light modulation element. Applying an electric current to this element inverts the magnetization direction of the light modulation layer. When a polarized light is incident from the transparent electrode side of the spin-SLM, in which pixels are arranged in two dimensions, the light is diffracted by the minute pixels. The diffracted light whose polarization plane is rotated by the magneto-optical Kerr effect of the light modulation layer causes interference in the air. This enables the display of 3D images.

To increase the density of the spin-SLM with a pixel pitch of 5 \( \mu \text{m} \) that we prototyped in FY 2014, we modified the design of the metal oxide semiconductor (MOS) transistor unit and developed a driving silicon backplane with a pixel pitch of 2 \( \mu \text{m} \) and its external drive circuit. The silicon backplane has 100×100 or 1000×1000 pixels. It contains driver circuits equipped with a shift register that can select 10 – 100 rows (columns) of pixels with a single input terminal. We also prototyped a 2D spin-SLM consisting of minute pixels by precisely connecting the drain of the MOS transistor unit with a TMR light modulation element (Figure 1). We measured the electrical resistance of the element by applying a very small external electric current to the spin-SLM and confirmed successful operation of its basic functions.

We fabricated an ultra-high-density magnetic hologram for still images (with a 1 \( \mu \text{m} \) pixel pitch and 10k×10k pixels) using patterned magneto-optical materials to verify the feasibility of displaying 3D images with this technology. By applying a hologram data conversion technology using computer generated holograms and photograph-based integral imaging information, we confirmed that the 3D image based on a photographed image could be reproduced with a viewing-zone angle of 36 degrees and that the reproduced image could be turned on and off by applying an external magnetic field to the hologram. This technology can be used as a 3D image information input method for SLMs.

This research was supported by the National Institute of Information and Communications Technology (NICT) as part of the project titled “R&D on Ultra-Realistic Communication Technology with Innovative 3D Video technology.”

Beam steering device

For a future integral 3D display that would have much higher performance compared with the current display, we are developing a new beam steering device that can control the direction and shape of light beams from each pixel without using a lens array. Controlling the direction and shape of light beams at high speed would enable reproduction of 3D images having both a wide viewing zone and high resolution. In FY 2014, we began to study on the beam steering device with an optical waveguide array using electro-optic materials that can control the refractive index at high speed by applying an external voltage\(^{(2)}\).

In FY 2015, we designed and fabricated a multi-channel optical waveguide array that confines light in a micro space in order to achieve precise deflection control. For designing the device dimensions, we developed a light wave propagation simulator that can quantitatively analyze the dependence of the phase shift of light on the applied voltage, and the crosstalk between channels. Using the simulator, we analyzed various characteristics of the deflection angle and spread angle of the light beams by using the number of channels and shape of the...

Figure 1. AM driving TMR 2D spin-SLM prototype (with a 2 \( \mu \text{m} \) pixel pitch and 100x100 pixels)
optical waveguides were used as parameters. On the basis of the analysis results, we fabricated the optical waveguide array and evaluated its characteristics.

[References]
3 Internet technology for future broadcast services

We continued our research on how to use the Internet to provide programs, news and information in the era of convergence of broadcasting and telecommunications.

Our work on broadcast-linked cloud services included conducting verifications of functions described in the Hybridcast Technical Specifications version 2.0 established by the IPTV Forum in FY 2014, participating in further standardization activities, and developing benchmark tests. As to the development of new standards, we contributed to a revision of the operational guidelines for MPEG-DASH (Dynamic Adaptive Streaming over HTTP) and Timed Text Markup Language (TTML) closed-captioning. With the aim of using MPEG-DASH as a video distribution method for Hybridcast, we developed and tested a player supporting MPEG-DASH.

In preparation for the start of 8K Super Hi-Vision (SHV) test broadcasting in 2016, we contributed to revisions of standards and establishment of operational guidelines for multimedia broadcasting at the Association of Radio Industries and Businesses (ARIB). We verified the new ARIB-TTML standard for the coding of subtitles and superimposed characters that is also applicable to telecommunications services.

Regarding our studies on the convergence of broadcasting and telecommunications, we are researching service systems that will offer new user experiences beyond those of conventional TVs. We examined services that provide program-related information to mobile devices and designed a future living space with an 8K Super Hi-Vision touch display. We also conducted subjective evaluations of Augmented TV, which is a new augmented reality (AR) technology linking TV and mobile devices and created a demonstration content of Augmented TV for digital signage application.

In our research on utilization of program-related information, we developed application programming interfaces (APIs) to get program-related information structured as Linked Open Data (LOD), released program guide information in the LOD format, and prototyped educational applications using semantic web technology.

In our research on program analysis technologies, we developed scene analysis systems for the automatic recognition of cast members in each shot and for the automatic tracking of a soccer ball in soccer game footage. We conducted viewing behavior experiments and explored the relation between viewing certain video content and facial expression changes and bodily reactions. We also prototyped a visualization system that enables users to find scenes that drew a lot of viewer responses in the form of postings on social network services (SNS).

In our research on distributed server-based broadcasting systems, we added a function for tag zapping to our time-shift zapping system and evaluated its effectiveness. We also developed a system that runs its viewing software on a cloud server so that the range of programming is not limited by the viewing terminal’s performance.

In our research on video distribution technologies, we investigated video stream generation techniques and MPEG-DASH player technologies to distribute video stably to a diverse variety of terminals such as TVs, PCs and smartphones. We identified issues with implementing MPEG-DASH in browsers, and together with commercial broadcasters, we reported them at a technical meeting of the World Wide Web Consortium (W3C).

Regarding security technologies, we researched an attribute-based encryption system that securely stores and provides viewer information on cloud servers and developed an encryption scheme that executes part of the encryption on the cloud to reduce the processing burden of the viewing terminal. We also studied cryptography technologies to prevent illegal copying of the receiver’s decryption key and update technology for scrambling encryption schemes.

3.1 Broadcast linked cloud services

Since its launch in 2013, Hybridcast has steadily expanded its services by welcoming new developments such as program-related services and participation of commercial broadcasters. In FY 2015, we worked on advanced services and on promoting Hybridcast. We also worked on domestic and international standardization and held demonstrations in preparation for the test broadcasting of 8K Super Hi-Vision.

Advanced Hybridcast

In June 2014, the IPTV Forum established Hybridcast Technical Specifications ver. 2.0. The specifications describe services that incorporate more functions into Hybridcast such as high-precision synchronization of broadcasting programs and broadband content, Video on Demand (VOD) using MPEG-DASH (Dynamic Adaptive Streaming over HTTP), non-broadcast-oriented managed (third party) applications, and common device linkage protocols that are independent of the specific receiver.

We actively participated in standardization activities both at home and abroad on high-functionality Hybridcast. We contributed to the establishment of Hybridcast Operational
Guidelines ver.2.2 that reflects the revised MPEG-DASH standards and specifications for Timed Text Markup Language (TTML) closed-captioning. We also helped to revise the ARIB standards related to these new functions. In parallel with these standardization activities, we exhibited our work at the NHK STRL Open House 2015 and other venues.

In our research on high-precision synchronization technologies, we demonstrated a way of synchronizing a broadcast program shown on the main screen with separate video transmitted to a tablet device by broadband network (Figure 1) as well as a way of presenting program-related data such as text and graphics showing players who scored goals and a scoreboard in synchronization with the broadcast(1) (Figure 2). We also verified that synchronized presentations could be made by using MPEG-DASH as a video distribution scheme for tablet devices(2).

To promote the use of MPEG-DASH content delivery technology for Hybridcast, we developed a player, created test streams, and verified the operations on various manufacturers’ TVs. We collaborated with commercial broadcasters to ensure that a diverse range of requirements, such as those on inserting advertisements in programs, could be met. The results of this research were exhibited at the Open House 2015 (Figure 3).

The Hybridcast system is designed to let service providers other than broadcasters develop apps for it. These “non-broadcast-oriented managed” apps are available on any channel, and because of that, they enable new services and business models. In FY 2015, we studied how these apps operate at the same time as apps enabled to work with only certain broadcasters, in particular how they operate when changing channels (Figure 4).

Standardizing a communication protocol between TV and linked terminals will enable terminal linkage by using the same companion apps (or common companion apps) on TVs of any manufacturer. We examined the specifications of the common communication protocol and common companion apps and conducted demonstrations in cooperation with the IPTV Forum.

We plan to continue with prototyping and verifications of various services along with standardization of operational guidelines with the goal of developing more high-functionality services.

### Promotion of Hybridcast

We worked with the IPTV Forum to promote Hybridcast. The availability of benchmark tests for Hybridcast would save labor in application development and increases service quality by providing applications for objectively assessing the performance of compatible TVs. In FY 2015, we developed a measurement system and test items in order to determine the processing performance of TVs running Hybridcast apps. The system was shown to member companies at a performance test event hosted by the IPTV Forum in September 2015. We plan to develop test systems for MPEG-DASH operations including ones for measuring network processing performance.

Besides these domestic activities, we strengthened ties with international standardization organizations. Our efforts included addition of the VOD method to an International Telecommunication Union, Radiocommunication Sector (ITU-R) technical report, a presentation and demonstration of high-functionality Hybridcast at the Technical Plenary/Advisory Committee Meeting (TPAC) of the World Wide Web Consortium (W3C) held in Sapporo, and a presentation on hybrid systems at the Asia-Pacific Broadcasting Union (ABU).

Through these activities, we tried to increase recognition and understanding of Hybridcast internationally.
SHV multimedia broadcasting

In preparation for the SHV test broadcasting scheduled for 2016, we conducted R&D on multimedia broadcasting with an eye to revising the standards, establishing operational guidelines, and conducting experimental verifications.

We examined specifications for channel selection and for sharing the storage of current receivers between conventional and SHV recordings. These specifications would be added to the ARIB standard for SHV broadcasting that was established in 2014. We also contributed to the establishment of operational guidelines. We sent a proposal to ISO/IEC and its domestic committee on adding Electronic Program Guide (EPG) symbols to its SHV specifications. We also developed an experimental system to verify data transmissions sent over broadcasting channels.

The ARIB-TTML standard was established for superimposing characters and closed-captioning on SHV multimedia broadcasting. The standard expands on the W3C TTML Recommendation to ensure the commonality and/or convertibility of broadcasting and telecommunications formats. We prototyped a system for conducting verifications of the functions of ARIB-TTML(3) and exhibited it at the Open House (Figure 5).

The TTML closed-captioning technology, which was also adopted for VOD services using MPEG-DASH, has been verified on a continual basis.

In order to make practical SHV multimedia services, we prototyped 8K Hybridcast services in which video is delivered through communication channels (Figure 6). We also examined problems that were encountered during the application development of previous prototypes(4).

In addition, we conducted research together with the Media Lab of the Massachusetts Institute of Technology on using 8K-SHV for other purposes besides broadcasting and on applications that can be used overseas.

Common access for broadcast and broadband

We designed a program viewing platform that has a common way of viewing programs delivered through different channels and VOD to different types of receiver terminals. We verified the functions of this media unifying platform(5) and exhibited it at Open House 2015 (Figure 7). We will incorporate the results of our research on distributed server-based broadcasting systems into this platform and make it the basis of future hybrid services.

References

3.2 Convergence of broadcasting and telecommunications

We are researching service systems that will offer new user experiences beyond those of conventional TV broadcasting by taking advantage of IT technologies such as the Internet and smartphones. Our research includes studies on expanding TV viewing experiences into real-life ones, designing a future living space with 8K, and applying augmented reality (AR) technologies to broadcasting.

**Program information provision services using mobile devices**

We are conducting R&D on providing program-related information to mobile devices for users who mainly use Internet media.

In FY 2015, we developed a prototype system to verify the feasibility of providing program-related information related to the places through which mobile users go. The system automatically extracts topics associated with places from EPG data and closed captions by using Wikipedia and presents users with program information related to places and events at the GPS location of their mobile devices. We plan to use this prototype to evaluate the effects of providing program information related to the user’s location.

**Design of a future living space with 8K**

We have been designing future living spaces with 8K Super Hi-Vision (8K) display to create new user experience and improve user satisfaction of interactive services. In FY 2015, we focused on new user interface for 8K experience and prototyped a touch interface for 8K display. This touch interface is built with an optical touch sensor that has a resolution beyond 8K. Moreover, it can handle popular touch events used on smartphones on HTML5 applications to increase affinity for 8K Hybridcast, because its application platform is considered as HTML5. Multiple users can also control the objects in the application on simultaneously at a large 8K display. Our prototype interface makes it possible to consider new design concepts for interactive services with 8K other than TV viewing.

**Device-linked system technology using AR**

We are studying augmented reality (AR) technology for broadcasting services. We conducted R&D on a device linkage system called “Augmented TV” that will provide a new viewing experience through mobile devices such as smartphones or tablets. This system will enable extra broadcast content to be shown in front of the TV screen by overlaying 3D CGs on the TV images shown on the mobile device.

In FY 2015, we conducted subjective evaluations investigating the influence of synchronization lag between camera images and telecommunications content displayed on a mobile device. The experiments used software to simulate Augmented TV in a CG-based virtual environment and precisely reproduce the synchronization lag. An evaluation video of a small black ball appearing to fly out of the screen was shown to test participants. The results showed that the permissible synchronization error time was around 0.03 seconds and that the synchronization method we developed is accurate enough.

In order to examine a ripple effect of Augmented TV on the content industry, we produced interactive content for a signage display in which ancient creatures depicted in the NHK Special Program “Leaps in Evolution” come out of the TV screen (Figure 1). Augmented TV was selected by the Ministry of Economy, Trade and Industry as one of 20 Innovative Technologies 2015 to promote innovation in digital content. We made a demonstration of Augmented TV at “Digital Content EXPO 2015” as the selected technology.

[References]


3.3 Program information utilization and program analysis technologies

To create new services that exploit the complementary advantages of broadcasting and telecommunications, we researched technologies for making use of program-related information, analyzing program scenes, and analyzing viewing habits.
■ Information network for broadcasting programs

To explore the possibility of broadcasters providing Internet services, we are studying ways to enable information related to broadcast programs such as on-air time and content description to be used in various services provided by both broadcasters and service providers. We are researching a program information data hub that structures program information into computer-readable Linked Open Data (LOD). In FY 2015, we designed new application programming interfaces (APIs) for enabling the services of other providers to use the data hub. The new APIs, which can be used in various ways, enable users to obtain all the information they need at once by making a simple query. Users who do not have any knowledge about complicated data structures can easily use the program information data hub. We demonstrated the effectiveness of the data hub and APIs by creating the following example Internet services for NHK health programs:

- A prototype health service equipped with a function to recommend information in programs related to the user’s interest by using semantic links on the “My Health” site service, which is currently in operation;
- The ‘My Health’ dictionary that can display health-program information related to the user’s interest any time on a web browser;
- A Hybridcast application that enables the viewer watching a TV program to use a tablet to get information on health-related programs and visit websites related to the keywords used in the program.

To investigate the feasibility of new applications and services using program data offered by non-broadcasters, we, in cooperation with the Programming Department, made APIs for using the data hub information available to external parties (Figure 1). We also participated in LOD Challenge Japan 2015, an open data event, as a data provision partner.

To explore new ways in which NHK’s content can be used in education[5], we developed applications for generating metadata and linking video content with encyclopedia services by using semantic web technologies. We also demonstrated that NHK content can easily interact with non-Japanese websites by using LOD.

■ Technology for generating viewing metadata

With a view to providing program-related information that matches particular viewing styles and viewer interests, we investigated the question of what program content attracts interest from the perspectives of program scene analysis and viewing behavior analysis. The program scene analysis involved a method for recognizing the main subjects in a video, while the viewing behavior analysis investigated viewers’ reactions while they watched programming as well as their use of Twitter and other social media.

Regarding the program scene analysis, we devised a method that automatically recognizes cast members in each shot for information programs. We conducted experiments with program video assuming the display of speech balloons and confirmed the effectiveness of the method[3]. We also developed a system for sports programs that automatically traces the path of a ball in soccer game footage (Figure 2). The system improves its tracking accuracy by learning properties of the motion of the ball. Tests at an actual broadcasting site demonstrated that the system is practical[5]. We also devised a technique for the stable tracking of fast-moving objects in other sports videos by using multi-viewpoint and infrared images.

Regarding the viewer behavior analysis, we tried to identify the relationship between the content of a piece of video and changes in the viewer’s facial expression and bodily reactions. We built a content viewing experiment environment in which the viewer’s lines of sight, pupil diameter, background activities, heartbeat, nose temperature, and facial expressions can be measured using multiple sensor devices. We analyzed facial expression changes and physical reactions of test participants while they were viewing various video materials. The results showed that some kinds of video tend to evoke certain reactions. This research was conducted in cooperation with Waseda University.

Regarding the SNS analysis, we prototyped a data visualization system that categorizes Twitter tweets by topic and interactively presents program scene corresponding to topics currently drawing a lot of attention, as a way of efficiently analyzing viewer responses to programs. This system enabled viewers to quickly find and watch program scenes that are the subject of many tweets on Twitter[5].

[References]

3.4 Internet delivery technology

With the aim of distributing programs over a network, we are researching a distributed server-based broadcasting system and video delivery technologies using the Internet.

- **Distributed server based broadcasting system**

  We continued with our study on a time-shift zapping system that allows users to select from the huge number of past programs by using easy zapping operations.

  The results of experiments conducted in FY 2014 showed that tag zapping is not used as much as time-shift zapping. To promote tag zapping, in FY 2015, we upgraded the operation interfaces of the program viewing software and enlarged the tag database. We reorganized the menu for selecting the type of zapping and added a function for zapping using thumbnail images to improve the operability of the interface (Figure 1). We also developed a tag-ranking method so that viewers can make more effective use of the tags related to the program they are watching. The method sorts the displayed tags by referring to genre information provided in the electronic program guide (EPG). It has a low calculation cost because it does not need to recalculate the tag frequency information.

  Using the upgraded viewing software, we conducted experiments that evaluated how easily a desired program can be found using tag zapping. The results showed that tag zapping enabled viewers to find many of the programs they desired to watch in a short time and after only a few zappings. We also developed a system to visualize the user’s viewing history by program zapping on the basis of viewing logs collected by the time-shift zapping system.

  For constructing a broadcasting system that can show a variety of broadcasting service without dependence of viewer device’s specification, we are developing a viewing system based on cloud computing technology, which runs viewing software on a cloud server and sends the processed result to the viewing terminal. In FY 2015, we operated the prototype system that we developed in FY 2014 on a commercial cloud service to evaluate its performance. We also added the simultaneous access function to the system for multi users, and modified the method of synchronization of video stream and audio stream.

- **Technologies of video distribution via the Internet**

  To support large-scale video distribution over the Internet, we are researching techniques for stable video delivery to a diverse range of Hybridcast-enabled TVs, PCs, and smartphones. In FY 2015, we investigated video stream generation techniques and MPEG-DASH player technologies. Regarding our work on the video stream generation technology, we conducted experiments on the video processing performance by the distributed processing we developed in FY 2014. On the basis of the findings of these experiments, we prototyped an MPEG-DASH video distribution system that divides up the processing of the video data among multiple servers and concatenates the processed fragments of the video stream in real time by checking their time stamps. Experiments confirmed that broadcast-quality video streams could be stably generated and clarified the relationship between the number of video streams and the required server scale. We also studied accelerating methods of the video stream generation. We reduced the traffic data between distributed servers by using a function to detect the memory size of the server and to determine the portion of the video data to be processed by one server in accordance with the detected value. Experimental results showed that the system generated video streams more quickly than one without the function.

  In FY 2014, we equipped our MPEG-DASH player with a feature to measure reception-status such as network throughput. In FY 2015, using this function, we developed a method for controlling delivery paths for each terminal to avoid Internet congestion. More specifically, we developed and tested a function to decide the best delivery path to each player based on the analysis of collected reception-status information measured by each player on the distribution side and a function that each player changes the delivery path in accordance with the decision. We also built and tested an application for mobile devices that can switch the communication path from cellular networks to device-to-device networks that was built between other terminals when multiple viewers watch the same video.

  In addition, we conducted laboratory experiments that revealed issues with implementing MPEG-DASH in existing browsers so that even TV receivers that have CPU and memory performances lower than those of a PC can playback video stably.

  We reported the above issues to the Web and TV Interest Group meeting of the World Wide Web Consortium (W3C), which oversees international standardization for web technologies, in cooperation with commercial broadcasters. We also provided our MPEG-DASH player to IPTV Forum members so that they could test the interoperability of MPEG-DASH video delivery.

  [References]
3.5 Security technologies

To ensure the security and reliability of programming in the era of the convergence of broadcasting and telecommunications, we are researching cryptography and authentication technologies for privacy preservation, extension of broadcasting services, tracing unauthorized users and scrambling updates.

Cryptography/authentication algorithm for Internet

We researched cryptography technologies that can be used to provide secure and reliable broadcasting services, such as Hybridcast, that take advantage of the Internet.

Service providers need information about viewers in order to personalize services. As the number of providers increases, however, the burden of encryption increases on the viewer terminal. Also, when viewers want to receive unknown services, they should access new providers whom they have not accessed before. An efficient way to deliver the benefits of new or unknown services without increasing the burden on the viewer terminal is to store viewer information in the cloud server and allow any provider, not just known ones, to freely access the information. From the perspective of preserving viewers' privacy, however, it is best to restrict access to the information. To meet these conflicting conditions, we researched an attribute-based encryption system that enables the viewer to specify the access rights of providers to the information by using their attributes. To reduce the burden on the viewer terminal, we developed an encryption scheme that divides up the encryption process so that part of it can be handled by cloud servers\(^{[1]}\).

In FY 2014, we developed an application authentication system using a signature scheme capable of updating and revoking signing keys efficiently. We examined the operation conditions for signing key distribution servers and other aspects and upgraded the system into a more practical one\(^{[2]}\).

How to use a cryptographic technology for tracing unauthorized users

We researched a method to use an encryption scheme for tracing unauthorized users as a countermeasure against illegal copying of receiver decryption keys.

To identify which receiver has been used to make an illegal copy of the decryption key, each receiver needs to have a unique decryption key. It is also necessary to test the pirated receiver created using the copied decryption key in order to determine the key. If the pirated receiver detects this test, however, it can interrupt the test by stopping operation. To prevent this from happening, we devised a content delivery method that makes a test indistinguishable from an actual service\(^{[3]}\).

Scramble update technology

To maintain the security of the scrambling scheme, we researched ways of updating encryption methods.

Both the old and new encryption methods are used during the encryption method update. Moreover, pirated receivers can reproduce part of the image though they cannot display it full-screen. We evaluated the security of this update method and demonstrated that it is practically secure\(^{[4]}\).

[References]

4 Technologies for advanced content production

We are progressing with our R&D on advanced program production technologies, including those for new content services and wireless technologies for program contributions such as emergency reports and live sports coverage.

In our work on video indexing technology, we conducted research on a video asset management system, called “Video Bank,” for assisting producers in video search and manipulation tasks. On the basis of our previous object recognition technology, we developed a new person identification method using “region-based” feature values that are not significantly affected by variations such as lighting conditions and facial expressions. This method improved the accuracy of person searches. For video production, we improved the functionality and accuracy of our hybrid sensor and installed it in an actual program production environment.

We are researching content utilization technology that uses text information to make better use of huge amounts of previously broadcasted content. We developed a method of related search for programs that uses semantic relations between words. We also developed interfaces for presenting program producers and viewers with programs related to the keywords and for enabling users to select a program or scene from a comprehensive view.

In our research on bidirectional field pick-up units (FPUs) for high-speed wireless transmission of file-based video footage, we examined adaptive modulation and retransmission scheme for improving the file transmission throughput and prioritized transmission scheme for live video transfer. We also prototyped experimental units to verify the feasibility of multistage relay transmission using bidirectional FPUs.

We are also researching a 4×4 multiple-input multiple-output (MIMO) scheme with four transmitters and four receivers for an 8K Super Hi-Vision wireless camera. We evaluated the transmission characteristics of a prototype using QPSK (Quadrature Phase Shift Keying) and upgraded the prototype to increase the modulation level to 16QAM (Quadrature Amplitude Modulation). In our research on single-carrier transmission technology for a more compact and higher-output-power wireless camera, we studied a wide-band transmission system that operates at 200 Mbps and built a prototype. We also improved the operability of our Hi-Vision wireless camera and used it for live coverage of golf tournaments and the NHK Kouhaku year-end music show.

4.1 Video indexing technology

Video indexing technology

To make use of raw video footage stored in video archives and to enlarge the range of expression for video, we are prototyping a video asset management system called “Video Bank.” Video Bank uses video analysis and sensing technologies to automatically add metadata that are helpful for searching and manipulating video.

On the basis of the object recognition technology we had developed earlier, we developed a video retrieval technology for identifying persons appearing in program footage. The previous technology was sensitive to variations in lighting conditions, head directions, and facial expressions in program video. To address these problems, we developed a new recognition method that is based on region-based feature values (i.e. feature values calculated for regions divided into different sizes). The new method does not require feature points to be detected. We conducted experimental evaluations in which about 20 actors/actresses were recognized in about 120 episodes of dramas. The experiments achieved an average precision rate of 98% for the top 50 persons in the search results. This recognition accuracy is very high, 18% higher than that of conventional techniques.

We continued with verification experiments on our visual-based image search technology that uses visual similarities in the entire image by linking it with NHK’s archives search system. Reviews of user operation logs and interviews with operators demonstrated its effectiveness at finding videos that could not be obtained with ordinary keyword searches. At the same time, the results revealed issues such as the need to improve the accuracy of the extracted subject area in the image and the necessity of adopting face recognition. Hence, we developed a method for extracting a subject area by using a dynamic contour model to detect the area of an object much precisely. This improved the accuracy of the visual-based image search.

We researched a method for extracting character strings from images for the purpose of recognizing text in scenes. This method will enable more effective video retrieval because it obtains information such as the name of a person or a place directly from the image. We studied ways to detect shapes that constitute character strings from character shape candidates detected in the input image. We devised a way of grouping these character shape candidates by detecting the stroke width of the character image that we had developed in FY 2014. We also developed a complementary method for re-detecting character strings that failed to be detected for the first process due to complexity of Japanese characters.

We continued our support for the experimental use of the Metadata supplementation system for earthquake disaster archives at the NHK Fukushima station and Morioka station for the purpose of organizing and managing a huge amount of video reports on the Great East Japan Earthquake. We installed an identical system at the NHK Sendai station to investigate the various ways in which it can be used and to collect information on how to improve video searches. On the basis of this work, we built a more versatile system that can be used on any kind of programs. We increased its practicality by adding a face
recognition function to identify specific persons, a wide variety of object recognition models, and a function to add or modify metadata at the time of a checking search results. In cooperation with the Rights & Archives Management Center, we added a function to re-organize news items with the aim of archiving video stored at local broadcasting stations. We cooperated with NHK Media Technology in a verification of the operations of the metadata generation system in a cloud environment.

Regarding our work on video processing technology, we improved the method for estimating studio lighting conditions that we developed in FY 2014 for natural synthesis of computer graphics (CGs) and real scene. The original method handled only monochrome lighting, whereas the improved method also works with colored lighting through its use of color chart calibration. Subjective evaluations showed that the method is capable of synthesizing natural appearing images, and demonstrations conducted in an actual studio production environment confirmed its practicality.

We improved the video segmentation method designed to use for pre-processing of video extraction, that is quite frequently used for video manipulation. Previously, segmentation data were handled as one space-time volume, and this requires a lot of memories. We introduced a new frame-based video segmentation method, which stores inter-frame connection path of segmented area between adjacent frames. This improvement extended the length of video that can be handled.

For video synthesis aiming a wide range of production effects, we improved the functionality and accuracy of hybrid sensors that measure camera movement which are sent to a CG drawing device. To measure lighting information when capturing video, we developed a function to obtain the luminous intensity and color information by rapidly rotating an 18-channel RGB sensor in the horizontal plane and performing scanning of the whole upper hemisphere. The effectiveness of this function was verified. We also added a new mechanism for estimating the distance between the camera and the subject from lens focus information and for expressing the back and front relationship between the main subject and CG object. Hybrid sensors were installed at the NHK Broadcast Center and Museum of Broadcasting. Part of this research was conducted in cooperation with Shimizu Corporation.

To determine how our video processing technologies can be used for other purposes, we provided assistance for video production operations. We worked with the Broadcast Engineering Department to develop a real-time lighting control system using image processing, which was exhibited at the NHK program production technology exhibition. We also examined ways of reducing light flickering in video (flash effect).

[References]

4.2 TV contents utilization using text information

To make better use of the massive TV program database that has accumulated over the years, we are researching content utilization technology to search for programs that are likely to interest users. We had earlier built Concept Map, which is a network of semantic relations between words, from web text. Concept Map is the basis of program retrieval and presentation technologies. For example, Concept Map may connect the words “diabetes” and “insulin” through the semantic relation “remedy.” In our research on program retrieval technologies, we devised a search method that uses Concept Map and the similarity between words, and we demonstrated its effectiveness in experiments by weighting links between nodes on Concept Map, we made it possible to retrieve related programs even if the search keyword is not directly included in program descriptions.

In our research on program presentation technologies, we developed a user interface using semantic relations of words and program-related information in the software-readable Linked Open Data (LOD) format. This interface makes it easy to retrieve and present programs that are related to the words in web content. For example, if the user selects the phrase “cerebral infarction” that appears in the web content, the interface displays semantic relations such as “remedy” and “prevention,” followed by programs whose topics are “Remedies for cerebral infarction” and “Prevention of cerebral infarction.” We also devised a clustering method to visualize a huge amount of programs and scenes and developed a user interface giving an “overhead view” of programs in the database.

[References]

Figure 1. Program presentation interface used for “Health for Today”
4.3 Bidirectional field pick-up unit (FPU) transmission technology

We are researching bidirectional field pick-up units (FPUs) for making high-speed wireless transfer of file-based video footage. In FY 2015, we shortened the time of file transfer by improving a retransmission control and an adaptive modulation scheme, and shrank latency of real-time video transmission by prioritized transmission control. We also prototyped an experimental device to verify multistage relay transmission using bidirectional FPUs.

Regarding the adaptive control for shortening the time of file transmission, we confirmed that Hybrid Automatic Repeat request (HARQ), which combines error correction and automatic repeat request, can raise averaged throughput over that of Transmission Control Protocol (TCP), which recovers errors using automatic repeat request only. While higher-order modulation can increase the capacity of wireless link, doing so is prone to errors when the reception quality is low; this causes throughput to deteriorate because of frequent retransmissions for error recovery. An investigation on the relationship between the modulation level and throughput showed that there is an optimum modulation order that yields the highest throughput for each reception quality (Figure 1). We therefore examined an adaptive control method that selects the modulation level for the maximum throughput according to the reception quality and confirmed its effectiveness in laboratory experiments.

For prioritized transmission control method for transfer of live video, we examined a method to preferentially transmit packets that need to be transmitted live. A bidirectional FPU must be able to transmit a live video stream reliably and with low latency as well as transfer recorded video footage quickly. In FY 2015, we added a prioritized transmission control method for live video transfer. The method uses strong error correction instead of retransmission on packets of a live stream and transmits those packets before other packets that do not need to be transmitted live. We confirmed that the method can suppress any increase in latency of live transmission packets even in the cases of channel quality deterioration and congestion.

For investigating characteristic of multistage relay transmission with bidirectional FPUs, we prototyped an experimental device to evaluate the influence of radio wave interference. Video contributions that are sent from the reporting site to the broadcasting station may have to go through chain of relay FPUs when the outreach of a single FPU does not cover the whole distance. A bidirectional FPU uses the time division duplex scheme, which enables bidirectional communications over a single channel by quickly switching between the uplink and downlink. This means that each of the two FPUs repeats transmitting and receiving radio waves at a relay point in a multistage relay. This may cause radio wave interference in an amount depending on the timing of the transmissions and receptions of the two FPUs. In order to evaluate the effect of the radio wave interference, we prototyped an experimental device to adjust the signal transmission timing to an arbitrary time lag. In addition, we reduced the size of our transmission and reception radio frequency (RF) unit, which previously needed to be placed on the floor. Our new RF unit is compact enough to be set up on a tripod (its portability is good). We also improved the operability and line quality of antennas by a new antenna interface which directly connects the transmission/reception radio frequency unit and the antenna without a cable.

4.4 Wireless cameras

We researched elemental technologies for an 8K Super Hi-Vision wireless camera, including a 4×4 (four transmitters and four receivers) multiple-input multiple-output (MIMO) scheme for expanding channel capacity and single-carrier transmission with frequency domain equalization (SC-FDE) for achieving a more compact and higher-output transmitter. We also improved the operability of our Hi-Vision wireless camera (millimeter-wave mobile camera) and used the camera for shooting various programs such as golf tournaments and the NHK Kouhaku year-end music show.

4×4 MIMO transmission technology

We are studying 4×4 MIMO transmission technology in order to expand the transmission capacity of wireless cameras. This technology can double the transmission capacity of
conventional MIMO system with two transmitters, however, it requires more computations on the receiver side to perform maximum likelihood detection (MLD) of signals. To address this problem, we have reduced the amount of MLD computation by applying 'block QR decomposition' to the channel matrix between the transmitting and receiving antennas. In FY 2015, we evaluated the transmission performance of a 4×4 MIMO-QPSK (Quadrature Phase Shift Keying) demodulator with the reduced computation method (Figure 1). The results showed that the demodulator was capable of stable transmissions while reducing the MLD computations to about 65% of conventional ones\(^1\). We also developed a technique to reduce the MLD computations even more and upgraded the prototype system to support 16QAM (Quadrature Amplitude Modulation). In addition, we prototyped an antenna unit containing two transmitting antennas. Two of these units would achieve a compact set of four transmitting antennas suitable for the wireless camera system.

**Single-carrier transmission with frequency domain equalization (SC-FDE)**

We are researching the SC-FDE scheme in an attempt to develop a more compact and higher-output transmitter for wireless cameras. In FY 2015, we studied the parameters of a wide-band 200-Mbps-class transmission system and evaluated the effect of non-linear amplification by a millimeter-wave-band power amplifier and the transmission characteristics through computer simulations. The results showed that the SC-FDE scheme has a less signal distortion than the orthogonal frequency division multiplexing (OFDM) scheme even when the millimeter-wave-band power amplifier operates at a high output power, because signals of single-carrier transmission have a smaller difference between the peak power and the average power. This means the SC-FDE scheme can have a larger link margin, though the required carrier to noise ratio deteriorates slightly\(^2\). In addition, we prototyped an experimental system implemented with the transmission parameters for the wide-band system.

[References]


5 User-friendly broadcasting technologies

Everyone, even people with vision or hearing impairments and non-native speakers, should be able to enjoy broadcasting content and services. We are conducting research on technologies for making broadcasting more user-friendly, i.e., easier to listen to, view, and understand.

In our research on user-friendly presentation of information, we developed sign-language CG characters that have facial expressions as presenters of weather information. We developed a system for automatically generating sign-language CGs from weather forecasts distributed by the Japan Meteorological Agency. Subjective experiments indicated that the sign-language CGs are understandable. We also improved the movements of the CG character’s mouth and created a way of manually modifying unnatural motions and gestures. In our study on technologies for kinesthetic display of images and 3D objects, we developed a device for presenting the shape and hardness of an object by providing kinesthetic stimulation to the user’s thumb and forefinger. We also conducted subjective experiments on our tactile presentation device for conveying 2D information such as graphs and maps.

We refined our speech recognition technology for closed captioning by improving robustness against background noise and inarticulate speech. We also upgraded our algorithm for captioning so as to estimate caption texts accurately. The algorithm was put to use at a local broadcast station. To use speech recognition for closed captioning of broadcasts during disasters and other emergencies, we developed a system for collecting emergency information efficiently and updating the language model for speech recognition. The device was put into operation in a closed-captioning system for news programs.

We also researched speech synthesis and processing technologies for expressive speech. Our research on speech synthesis has been incorporated in test broadcasting of automatic weather reports. We also created a speech synthesis framework for enhancing the quality of the synthesized sound and data for training statistical models for speech synthesis. We improved a method for adding emotional expressions to speech by using the differences in acoustic feature values between emotional and emotionally neutral voices. In order to suppress background sound, we optimized three functions: speech rate conversion for making speech in a broadcast easier for the elderly to listen to, background noise suppression, and speech enhancement. We developed a versatile library that can be used with PCs and smartphones.

In our research on Japanese-language conversion and analysis assistance, we developed technology for assisting with the task of converting news program scripts into "easy Japanese" for the benefit of non-native speakers in Japan. We developed a method for dealing with words that are difficult to replace with easier Japanese. Evaluation experiments were also conducted. In our development of technology for analyzing viewers’ opinions of programs, we developed a method for categorizing a large number of opinions by the similarity of their content. In addition, we developed a tweet analysis system for producing “Data NAVI” programs.

In our research on image cognition analysis, we investigated image features suitable for a wide viewing environment such as 8K Super Hi-Vision. We conducted psychological experiments to measure the preferred size of displayed image for various kinds of scenes and obtained knowledge on image features appropriate for wide-angle viewing. We also researched technologies to estimate the degree of unpleasantness caused by shaking images on the basis of cognitive features of the shaking movements.

5.1 User-friendly information presentation technology

NHK STRL is researching technology for translating weather information into sign-language CGs as well as kinesthetic display technology for conveying the shape and hardness of a 3D object so that people with vision and hearing impairments can enjoy broadcasts.

- **Sign-language CGs with facial expressions for presenting weather information**

To enhance services for viewers who mainly use sign language, we are researching technology for automatically translating Japanese weather reports into sign language animations using computer graphics (sign language CGs).

Mouth movements (“mouthing”) play an important role in interpolating information in sign language. For example, the name of a place can be recognized as a proper noun by using mouthing to express its pronunciation. We developed a mouthing production system for sign language CGs in FY 2015. The system produces complex mouthing patterns by connecting together basic mouthing CGs expressing vowels, etc., that are created in advance. This improved the naturalness of the CG character’s mouth movements as the mouthing of sign language. We also developed a tool that enables the operator to adjust the time period of displaying mouthing patterns and the way of the CG character’s mouth opens at the same time checking the movements of the character’s head and fingers. We also added transcriptions of mouth patterns to our sign language news corpus that contains transcriptions of manual gestures.

To produce sign language CGs, it is necessary to connect the
sign language word motions, each of which is created using motion capture from a real human signer, to generate a continuous movement that corresponds to the sign language sentence. The hand movements automatically generated by the conventional method may be unnatural at junctions between words. To address this problem, we developed a technology that enables the operator to modify such unnatural movements manually. But even if the hand movements are determined, the elbow and shoulder joints still have degrees of freedom. We thus prototyped a system that solves the inverse problem to determine the joint angles of the elbow and shoulder corresponding to the hand position by using a high speed algorithm. These developments have enabled real time CG production.

Besides our work on sign language CG translation of free texts, we developed a system for automatically generating sign language CG utilizing prefixed phrases (2) (Figure 1). This system uses the latest weather information in XML format distributed by Japan Meteorological Agency to automatically generate sign language CGs that convey the weather forecast, maximum/minimum temperatures and probability of rainfall for prefectural capitals in Japan. To assess the quality of these CGs, we conducted psychological experiments in which we asked deaf people whose first language is sign language to verify the meanings of the sign language CG messages. The percentage of correct answers in the experiments was 96.5%, which demonstrated that the sign language CGs were sufficiently understandable. Part of this study was conducted in cooperation with Kogakuin University.

### Technologies for kinesthetic display of images and 3D objects

We are researching a system for enabling users to understand with their fingers the virtually expressed shape and hardness of a 3D object and a pin-array display system for presenting 2D information such as maps and graphs.

In our research on conveying the shape and hardness of a 3D object, we had earlier developed a means of obtaining data on the shape and hardness of 3D objects and a device for conveying such information to one finger. In FY 2015, we prototyped a device that expresses the shape and hardness of an object through kinesthetic stimulation when the user makes the motion of holding an object with his/her thumb and forefinger (Figure 2). This device can express a curved surface or the angle between two intersecting planes of the object by giving stimulation to three points on each finger. It can also present the hardness of a plane by giving a reactive force to the finger “pressing on the surface”. We conducted experiments in which users of this device tried to recognize the diameter size of a cylindrical object displayed by it. The results showed that it is possible to convey the object’s size by presenting the inclination of the curved surface. Part of this research was conducted in cooperation with the University of Tokyo.

We are researching a system that expresses 2D information such as maps and graphs by using pin arrays that move up and down to form lines and surfaces perceptible by touch. The user can perceive the outline, shape, and relative positions of objects by moving his/her finger along the lines and surfaces. We previously developed a method for displaying outlines of shapes and routes on a map by using pin arrays, a system for guiding the user’s finger, and an authoring tool for easily creating content to be presented by the system. In FY 2015, we incorporated into our system the know-how of a caregiver advising a visually impaired person on important points while guiding his/her finger. In addition to continuous finger guidance, we added a control to stop the finger and move it up and down at an important point as well as a function to slow down the finger guidance at regular intervals to show the distance between graph scales. The results of subjective evaluations by visually impaired students demonstrated the effectiveness of our proposed method. Part of this research was conducted in cooperation with Tsukuba University of Technology.

[References]


5.2 Speech recognition technology for closed captioning

We are researching speech recognition for efficiently producing closed captions for live programs so that more people including the elderly and those with hearing difficulties can enjoy TV programs.

**Conversation recognition**

The accuracy of speech recognition in a TV program declines when there is background noise and inarticulate speech during a conversation. When possible, a re-speaker can be employed to increase the recognition accuracy in such situations. A respeaker works in a quiet room and speaks or rephrases the original noisy or inarticulate speech, which is then automatically recognized for captioning. However, many local broadcasters cannot afford to employ a re-speaker. Thus, for them to produce closed-captioning for information programs, it is an urgent task to develop a way of automatically recognizing program audio without the need for re-phrasing.

For direct recognition of conversational speech, in FY 2014, we developed a deep learning model based on neural networks to increase recognition accuracy. In FY 2015, we improved the language model[3] so that it can handle grammatical ambiguities appearing in conversations by creating models of obscure contexts using neural networks and robustly estimating the probability of word appearances for each context.

In addition, we studied a technology for estimating speech variability in order to handle ambiguous pronunciation in conversations. In FY 2015, we improved our pronunciation dictionary by integrating multiple translation models for estimating the variability by optimal weight[4].

We also improved the technology for automatically building a corpus for training speech recognition systems as to the frequency distribution of vowels and consonants in conversation from speech and closed captions of broadcast programs. In FY 2015, we developed a technology for estimating the accuracy of training data by mapping the frequency distribution of speech and phoneme sequences by taking into account that closed captions would have paraphrases and omissions compared with the actual spoken words. This accuracy estimation was incorporated in a model training method[5][6].

With these new technologies, we reduced the word recognition error rate of program audio selected for evaluation from a local information program, “Hirumae Hotto,” from 13% to 9.3%.

**Practical applications**

Training and hiring staff to correct recognition errors has been an obstacle of using speech recognition for closed-captioning. To address this problem, we earlier developed an algorithm for producing closed captions with less manual effort and put it into operation at the NHK Hiroshima station. This algorithm compares news scripts prepared in advance with the speech recognition result, estimates the text corresponding to the speech, and outputs the text as the closed caption. On the basis of our experience at the Hiroshima station, we added a function to assist with editing of preparatory scripts in order to reduce the delay of displaying closed captions by quickly determining the corresponding text. This upgraded closed-captioning system was put into operation at the NHK Matsuyama and Sapporo stations.

News and information programs that are broadcast during a large-scale disaster need to convey the latest information moment by moment. In order to use speech recognition for closed-captioning such programs, it is necessary to collect related words and information immediately and update the language model. We incorporated our experience of closed-captioning news coverage of the Great East Japan Earthquake into a prototype device for updating the language model by collecting emergency information from closed captions produced by other means than speech recognition and from corrections to speech recognition results. The news closed-captioning system incorporated in this device was put into service (Figure 1).

![Figure 1. Closed-captioning learning assistance device](image)

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[References]


5.3 Speech synthesis and processing technologies for expressive speech

We are researching speech synthesis and processing technologies enabling the use of expressive speech in user-friendly broadcasting services. For easy-to-hear readings and enriched production effects, we applied our speech synthesis technology to a wider variety of phrases and to add emotional expressions fitting the speech topic.
Speech synthesis technology

Our speech synthesis method that directly uses waveforms from a speech database is currently in operation for automatic broadcasting of the “Stock market report program” on NHK Radio 2. In FY 2015, we began test operation of automatic broadcasting of the “Weather report.” While this method is capable of high-quality synthesis of a limited vocabulary, sound quality deteriorates when words not in the database need to be synthesized for arbitrary sentences. To enhance the quality of the synthesized sound, we developed a hybrid method that combines the advantages of the method for directly using waveforms from a speech database and a new method that uses a statistical model created from the database. However, the results of subjective evaluations of these three methods did not show a significant difference in the naturalness of their sound[3]. We therefore built a new speech synthesis framework on the basis of the statistical model method and prepared training data for the model by using a massive amount of speech data accumulated for speech recognition research in order to deal with general topics.

Speech processing technology

We are developing a method for adding emotional expressions to neutral speech (that does not convey any emotion) by using the differences in acoustic feature values between emotional voices and neutral voices. While subjective evaluation experiments demonstrated that this method can add emotional expressions, it adversely affects sound quality. In FY 2015, we devised a method for minimizing the deterioration in sound quality by smoothing unnecessary differences in acoustic feature values between emotional and neutral voices and by processing only the feature values contributing to emotions. We conducted subjective evaluations using an emotional speech database and confirmed that sound quality improved[3].

Background sound suppression technology

We optimized and incorporated three functions, i.e., speech rate conversion, background noise suppression, and speech enhancement, in a signal processing method for making speech in programming easier for elderly persons to listen to and developed a versatile library for PCs and smartphones. Subjective evaluations demonstrated an improvement in ease of listening when using the system.

[References]

5.4 Language processing technology

We are researching technology for automatically converting normal news scripts into easy Japanese which constitutes the body of the web service NEWSWEB EASY. We are also researching technology to analyze opinions of viewers in order to utilize them in program production.

Japanese translation/conversion assistance technology

In FY 2015, we prototyped an automatic rewriting system for making news expressions easier and proposed a technique for simplifying sentence structures. The automatic rewriting system uses statistical machine translation technology. It learns a translation model, a collection of rewriting patterns, and a language model, which expresses the naturalness of easy Japanese. These models are learned from a large amount of sentence pairs of original and easy Japanese news that have been collected from the daily service of NEWSWEB EASY.

Training these models usually requires a massive amount of sentence pairs, but the amount so far collected is far from sufficient. The data shortage invites degradation of the word alignment quality between normal and easy sentences, which result in low quality translation model, the rewriting patterns. For this problem, we developed a method of preferentially aligning words that were not converted during the manual conversion process: a typical example is the proper noun[4]. We also introduced variables in the rewriting patterns, which successfully widened their applicability[5].

The automatic rewriting system was evaluated by four Japanese language instructors engaged in the daily NEWSWEB EASY production. They said it helped them to produce easy Japanese scripts even if it may make some errors. For simplifying syntax, we identified conditions that permit changing noun modifier clause into an independent sentence[6]. An automatic rewriting system incorporating some of the above upgrades was exhibited at the NHK STRL Open House 2015 (Figure 1).

Opinion analysis technology

In FY 2015, we developed a “clustering” method for the viewers’ opinions of programs based on the similarity in the messages. In order to reflect the semantic similarity of synonymous words with different writings, we investigated a method for converting words into distributed representations. A distributed representation is a vector consisting of words and their numerical values that are automatically learned with neural networks. Synonyms such as “otoko” and “dansei” (both meaning “man”) show similar vectors. In the experiment, clustering using distributed representations revealed advantages over the conventional method based on the raw word frequency[7]. This research was conducted in cooperation with Hotto Link Inc.

We developed a tweet analysis system for assisting producers
5.5 Image cognition analysis

We are conducting research on image features suitable for the wide-angle viewing environment of 8K Super Hi-Vision. Our aim is to identify the features of image preferred by and having great psychological impact on viewers in a wide field-of-view (FOV) environment and to utilize them in SHV video productions. In FY 2015, we measured the preferred size of FOV by viewers and investigated a technology for analyzing shaky images.

■ Measurement of preferred image size

We investigated the features of SHV image which are preferred to be viewed with a wide FOV by a psychological experiment. We measured the preferred size of FOV of images that contains various types of objects and scenes captured in various ways. The experiment was performed by displaying them to the participants varying display size (Figure 1). The results showed that the preferred size varied as the contents of image. Generally, sceneries were preferred to be viewed as large size, while small objects were preferred to be viewed as small size. We plan to extract effective features of images adaptive for wide-angle viewing environments.

■ Shaking image analysis technology

Viewers may feel unpleasantness like motion sickness when viewing video showing a lot of movement. We are researching a technology for analyzing such images and estimating the degree of unpleasantness caused by viewing them. We conducted psychological experiments to investigate how the cognitive quantity of shakiness, which quantifies the negative sensations in response to the shaking motion, varies with the physical characteristics of shaking images. Evaluation images in which the foreground was separated from the background were used in the experiments. We evaluated how the cognitive quantity of shakiness changes when the area of the foreground or the relative speed between the foreground and the background changes.

The results showed a relationship between each physical characteristic and the cognitive quantity of shakiness. We found that the cognitive quantity of shakiness increases so that the screen occupation ratio of the foreground becomes higher but saturates at a certain ratio and that the cognitive quantity of shakiness is larger when the relative movements of the foreground and background are opposite to one another or these have no correlation than when these are in same phase(1). We also developed an algorithm for estimating the cognitive quantity of shakiness on the basis of the results, then verified the validity of this algorithm through experiments.

[References]
6 Devices and materials for next-generation broadcasting

We are researching the next generation of imaging, recording, and display devices and materials for new broadcast services such as 8K Super Hi-Vision (SHV) and three-dimensional television.

Regarding our research on imaging devices, we made progress in developing imaging devices having 3D structures, low-voltage multiplier films for solid-state sensors, and organic image sensors. In our work on imaging devices with 3D structures, we prototyped an imaging device with 128×96 pixels by stacking an upper layer that has a buried photodiode with less dark current and a pulse generation circuit and a lower layer that integrates pulse counters for each pixel. This prototype showed the feasibility of a wide dynamic range imaging device with 16-bit output. Our work on low-voltage multiplier films for solid-state sensors with high-sensitivity included reducing dark current by changing the fabrication process and suppressing defects by reducing the size of the crystalline grains. Our work on single-chip organic image sensors with an image quality comparable to that of a three-chip camera included miniaturization of the transparent thin film transistor. We also studied imaging devices with new functions, such as a distance sensor using optical transparency.

In our research on recording devices, we continued with our work on holographic recording with a large capacity and high data-transfer-rate for SHV video signal. We also continued with our study on a high-speed magnetic recording device with no moving parts. We developed elemental technologies for holographic recording, such as high-efficiency dual-page reproduction, and prototyped a practical drive. We also developed fundamental technologies for increasing the speed of magnetic recording devices by refining magnetization simulations and searching for suitable magnetic materials.

In our research on displays, we investigated multiple-division scanning-drive displays for the SHV system and developed elemental technologies for realizing flexible large displays with a low-cost solution-based technique. In particular, we devised a back-side-driven panel capable of multiple-division scanning driving and prototyped driving-equipment to verify the effectiveness of the temporal aperture control drive method for suppressing motion blur on hold-type displays. As regards our work on elemental technologies, we developed a technology for fabricating solution-processed oxide TFTs at low temperature.

6.1 Advanced image sensors

We are researching advanced image sensor technologies to address issues with high-definition and high-frame-rate images of 8K Super Hi-Vision and three-dimensional television using spatial imaging technology.

Three-dimensional integrated imaging devices

We are researching pixel-parallel signal processing imaging devices with a 3D structure in our quest to develop an ultra-high-definition high-frame-rate image sensor that can be used as part of a future three-dimensional imaging system. These devices have a signal processing circuit for each pixel directly beneath the photoelectric conversion element. This enables signals from all pixels to be read out simultaneously so that a high frame rate can be maintained even if the pixel count increases (Figure 1).

We earlier prototyped an 8×8 pixel element that converts incident light into pulse signals in the pixel and verified the operating principle by counting the number of output pulses from the element. We also developed a pixel structure and circuit technology for increasing sensitivity and reducing dark current.

In FY 2015, we prototyped an imaging device with 128×96 pixels that incorporates the above technologies. The new device has a two-layered structure. The upper layer has a buried photodiode with less dark current and a pulse generation circuit, while the lower layer integrates pulse counters for each pixel. This structure enables a digital value corresponding to the light intensity to be output directly from the pixel. An example of image captured by the prototype device is shown (Figure 2). The device can output a wide dynamic range signal of 16 bits. It can also capture images even in low-light conditions owing to less dark current[10].

This research was conducted in cooperation with the University of Tokyo.

Figure 1. Schematic diagram of three-dimensional integrated imaging device

Figure 2. Example of image captured by the prototype device
**Low-voltage multiplier films for solid-state sensors**

The sensitivity of solid-state image-sensor cameras decreases as the number of pixels and the frame rate increase because the amount of light incident on each pixel decreases. As a countermeasure to this problem, we can enlarge the imaging device to get a larger pixel area in order to secure the necessary sensitivity. This, however, causes new problems such as a reduced depth of field and difficulty in downsizing the camera. To increase the sensitivity of the imaging devices without taking such an approach, we are developing a solid-state image sensor overlaid with a photoconductive film (low-voltage multiplier film) that is able to multiply the electric charge by applying a low voltage (Figure 3). In FY 2015, we reduced the dark current of chalcopyrite material films and suppressed defects (white blemishes) of crystalline selenium films. These are two candidate materials for low-voltage multiplier films.

We reviewed the deposition process of chalcopyrite material films to reduce the dark current. Continuous deposition of a p-n junction combining chalcopyrite film, which is a p-type material, and gallium oxide, which is an n-type material, in a vacuum chamber reduced the dark current to about one-tenth that of conventional methods.

White blemishes in images captured with a crystalline selenium film are presumably related to the lack of flatness of the film surface. We demonstrated that doping crystalline selenium with chlorine increases the flatness of the film surface (Figure 4) and suppresses the occurrence of white blemishes.

**Elemental technologies for organic image sensors**

We are conducting research on organic image sensors with an image quality comparable to that of three-chip color broadcast cameras.

We previously verified the operating principle of these imaging devices and developed elemental technologies for increasing the resolution such as miniaturization and thinning of the transparent thin-film transistors (TFTs). In FY 2015, we developed technologies for a Hi-Vision device. If the optical size of the image sensor is 35-mm full size (approximately 36 mm horizontal x 24 mm vertical), the pixel size for a Hi-Vision device needs to be 20 μm. This means that the materials of our TFT need to be further miniaturized by half. After a thorough review of the fabrication process of transparent TFTs, we prototyped a TFT with a channel length of 1.6 μm that supports a pixel size of 20 μm (Figure 5).

The TFT prototype achieved a mobility of 4.4 cm²/Vs and an on-current of 50 μA, similar to the values of conventional TFTs. It also achieved an on-off ratio of 10⁷ or higher, more than one order of magnitude higher than that of conventional TFTs (Figure 6). We thus showed the feasibility of a transparent TFT circuit for Hi-Vision.

This research was conducted in cooperation with the Kochi University of Technology.

**Monocular range image sensors**

We studied ways to incorporate new functions into our imaging devices by exploiting the advantages of optical transparent organic image sensors and existing silicon imaging devices. Specifically, we studied a sensor that can obtain image and distance information simultaneously through a single lens wherein the distance to an object is estimated from the amount of blur arising from the shift in the focal position caused by stacking two imaging devices (Figure 7).

The optical transparency of organic image sensors was evaluated through simulations on the intensity distribution of...
We also examined a multi-spectrum image sensor that combines an organic image sensor with a silicon imaging device using color filters.

[References]

### 6.2 Advanced storage technology

#### High-speed and high-density holographic memory

An archive system for storing 8K Super Hi-Vision (SHV) video for a long term will need a very high transfer rate and large capacity. We have been researching high-speed and high-density holographic memory to meet these needs. In FY 2015, we worked on high-efficiency dual-page reproduction technology for increasing the data transfer rate from holograms and on a prototype drive.

The dual-page reproduction technology that we developed in FY 2014 divides the reference beam entering hologram into p- and s-polarization beams and uses them to irradiate different holograms simultaneously. These two types of data reproduced from the hologram can be detected simultaneously by using a polarization isolation optical system, meaning that the data transfer rate can be doubled. In this process, most of the reference beam passes through the hologram. In FY 2015, we developed a new dual-page reproduction technology for changing the one-polarization reference beam into another polarization once it has passed through hologram and then using it to irradiate the hologram again. This technology is called reference-beam reusing dual-page reproduction (Figure 1). We confirmed that it can make effective use of laser light, enabling simultaneous reproduction of two types of data with almost the same level of laser power as the conventional reproduction method.

In our work on processing the reproduced signal, we used a graphics processing unit (GPU) in combination with a field-programmable gate array (FPGA) to reproduce SHV video that had been compressed to 85 Mbps by HEVC/H.265 from holographic memory in real time.

We also worked on a prototype holographic memory drive. To reduce the distortion in the reproduced data, we calculated the effect of applying the wavefront compensation technology that we developed in FY 2012. The calculation showed an order of magnitude improvement in the bit error rate from the 10^2 level of the previous technology.

This prototype drive was developed in cooperation with Hitachi, Ltd. and Hitachi-LG Data Storage, Inc.

#### Magnetic high-speed recording devices utilizing magnetic nano-domains

With the goal of realizing a high-speed magnetic recording device with no moving parts, we are developing the recording device that utilizes the motion of nano-sized magnetic domains in magnetic nanowires. In FY 2014, we verified the operation principle for this recording device, i.e. the formation (recording), detection (reproduction), and current driving of magnetic nano-domains by adopting a magnetic recording head used in a hard disk drives. In FY 2015, we have started the research on fundamental technologies for increasing the speed of these operations.

The sensitivity of the read head is high enough for high-speed detection of magnetization direction in each formed magnetic domains. On the contrary, the instability in the formation of magnetic domains by write head leads to recording loss. We therefore developed a new structure that has a soft magnetic underlayer (SUL) beneath the magnetic nanowire that helps to form a closed magnetic flux path among these structural components and improve the recording efficiency. We confirmed that this structure stably forms magnetic domains and reduces the recording loss, by both simulation and experiment.

We designed various models with different SUL shapes and investigated the formation of magnetic domains through...
6 Devices and materials for next-generation broadcasting

6.3 Next-generation display technologies

- **Multiple-division-scanning-drive-display**

We are researching ways to show full-specification 8K Super Hi-Vision video on an organic light-emitting diode (OLED) display. We investigated local area scanning drive technology as a means of achieving a higher frame rate and an adaptive temporal aperture control for suppressing motion blur on hold-type displays and extending the lifetime of OLEDs.

To divide an OLED display into multiple areas and drive them separately, we devised a back-side-driven panel structure, in which three-dimensional wiring is formed on the area level. We also prototyped a small substrate by using a metal pillar electrode that penetrates the back substrate of the panel. We devised a back-side-driven panel structure, in which three-dimensional wiring is formed on the back substrate. We also prototyped a small substrate by using a metal pillar electrode that penetrates the back substrate of the panel. We also prototyped a small substrate by using a metal pillar electrode that penetrates the back substrate of the panel. We also prototyped a small substrate by using a metal pillar electrode that penetrates the back substrate of the panel. We also prototyped a small substrate by using a metal pillar electrode that penetrates the back substrate of the panel.

As for the adaptive temporal aperture control, which was previously evaluated through simulations, we prototyped driving equipment that controls the temporal aperture in the drive IC units and experimentally confirmed the effectiveness of the control method with actual equipment. We also found that the image quality degradation caused by blinking artifacts that occur around the boundary between areas with different temporal apertures can be decreased by controlling the light-emitting timing appropriately.

- **Flexible displays**

We are aiming to develop ultra flexible large displays with a low-cost solution-based technique. In FY 2015, we developed a fabrication technology for solution-processed oxide thin-film transistors (TFTs) that will enable low-temperature formation. To increase the mobility of solution-processed oxide semiconductors, it is necessary to decrease solvent-induced impurities in the film, meaning that a curing temperature of more than 400°C is required. Meanwhile, the plastic that is used for the substrate of flexible displays has lower heat resistance than glass. It is therefore desirable that the TFTs can be fabricated at low temperature. To do so, we developed a technology that enables the maximum process temperature to be lowered by applying a hydrogen plasma treatment to solution-processed oxide semiconductors. We found that the solution-processed ZTO (Zn–Sn (Tin)-O) with the plasma treatment formed at 300°C improved mobility from 0.3 cm²/Vs to 3.1 cm²/Vs, which is higher than that of TFTs (without hydrogen plasma treatment) fabricated at 400°C.

[References]


7 Research-related work

NHK STRL promotes the use of its research results on 8K Super Hi-Vision and other technologies in several ways, including through the NHK STRL Open House, various exhibitions, and reports. It also works to develop technologies by forging links with other organizations and collaborating in the production of programs.

We contribute to domestic and international standardization activities at the International Telecommunication Union (ITU), Asia-Pacific Broadcasting Union (ABU), Information and Communications Council of the Ministry of Internal Affairs and Communications, Association of Radio Industries and Businesses (ARIB), and various organizations around the world. We also promote Japan’s terrestrial digital broadcasting standard, ISDB-T (Integrated Services Digital Broadcasting - Terrestrial), by participating in the activities at the Digital Broadcasting Experts Group (DiBEG) and International Technical Assistance Task Force of ARIB.

The theme of the FY 2015 NHK STRL Open House was “Countdown to the Ultimate TV!” It featured 26 exhibits on our latest research results such as 8K Super Hi-Vision, for which test broadcasting is soon to start in 2016, new broadcasting technologies utilizing the Internet, 3D television, user-friendly broadcasting, and advanced content production. The event also had nine poster exhibits and four interactive exhibits and was attended by 20,123 visitors. We also held 56 exhibitions in Japan and overseas.

We conducted 90 tours of our laboratories for 1,367 visitors. Thirty-two of these tours were for visitors from overseas.

We published 623 articles describing NHK STRL research results in conference proceedings and journals within and outside Japan and issued 12 press releases. We continued to consolidate our intellectual property rights by submitting 338 patent applications and obtaining 169 patents. As of the end of FY 2015, NHK held 1,886 patents.

We are also cooperating with outside organizations. Last year, we participated in 26 collaborative research efforts and five commissioned research efforts. We hosted three visiting researchers (two from overseas and one from Japan) and 21 trainees. We also dispatched four of our researchers overseas.

The equipment resulting from our research, including hybrid sensors for extensive image applications, wireless cameras using millimeter-wave-band radio waves, ultra-high sensitivity Hi-Vision HARP cameras, and “Insect Microphones”, was used in the production of NHK television programs. In FY 2015, NHK STRL collaborated with the parent organization in making 31 programs. Finally, in recognition of our research achievements, NHK STRL received a total of 38 awards in FY 2015, including the Meritorious Award on Radio and the Maejima Award.

7.1 Joint activities with other organizations

7.1.1 Participation in standardization organizations

NHK STRL is participating in standardization activities within and outside Japan, mainly related to broadcasting. In particular, we are contributing to the creation of technical standards that incorporate our research results.

The ITU Radiocommunication Sector (ITU-R) Study Group 6 (SG6) handles broadcasting standardization. As part of this group, we contributed to the establishment of Recommendations for the standard viewing conditions based on the high dynamic range television requirements and for the optical-optical transfer function (OOTF). We also contributed the results of our ultra-high-definition television (UHDTV) terrestrial transmission experiments using the space-time-coding single frequency network (SFN) for the next generation of terrestrial broadcasting, UHDTV signal transmission parameters for a 120-GHz-band field pick-up unit (FPU), and a method for converting UHDTV colorimetry (Recommendation BT.2020) content to HDTV colorimetry (Recommendation BT.709) content. At the meeting in October, a member of our laboratories was elected chairman of SG6. We also helped ITU Telecommunications Sector (ITU-T) Study Group 9 (SG9) for cable TV to issue three Recommendations (J.94, J.183, J.288) for the channel bonding technology, which is the cable transmission scheme for Super Hi-Vision.

At the Motion Pictures Expert Group (MPEG), we helped to establish implementation guidelines (ISO/IEC TR 23008-13) for the MPEG Media Transport (MMT) that are based on the ARIB STD-B60 standard for media transport schemes for 4K/8K Super Hi-Vision satellite broadcasting. We helped with performance improvements and sound quality evaluations of MPEG-H 3D Audio, a coding scheme for three-dimensional sound including 22.2 ch sound. Phase 1 for high-bit-rate specifications was standardized in February and released in October. For standardization of 3D coding, we submitted performance-evaluation technologies and test images of integral 3D television.

At the Society of Motion Picture and Television Engineers (SMPTE), we engaged in standardization activity for determining a timecode that supports up to 960-Hz frame frequencies.

This year, the first time, the Technical Plenary/Advisory
Research-related work

Committee Meeting (TPAC) of the World Wide Web Consortium (W3C), which overseas the HTML5 standard for describing content delivered through broadcasting and telecommunications, was held in Japan. NHK attended Web and TV Interest group (IG) to help identify technical requirements for applying web technologies to TV services and exhibited Hybridcast technologies.

The technical committee and general meetings of the ABU were held in Istanbul, Turkey. We reported on our development of sign-language weather reports using CGs and on Internet distribution and the security of broadcast content. We made presentations on our technologies including those of sign-language weather reports using CGs at a digital broadcasting symposium held in Kuala Lumpur in March 2016.

In addition to the above activities, we engaged in standardization activities at international and domestic standardization organizations, including the European Broadcasting Union (EBU), the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), the Advanced Television Systems Committee (ATSC: an organization standardizing TV broadcasting systems in the U.S.), the Audio Engineering Society (AES), the Japan Electronics and Information Technology Association (JEITA), and the Telecommunication Technology Committee (TTC) of Japan.

Leadership activities at major standardization organizations

| International Telecommunication Union (ITU) |
| Committee name | Leadership role |
| International Telecommunication Union, Radiocommunication Sector (ITU-R) |  |
| Study Group 6 (SG 6, Broadcasting services) | Chairman |
| ITU-R/ITU Telecommunication Standardization Sector (ITU-T) |  |
| IRG-IBB | Co-Chairman |

| Asia-Pacific Broadcasting Union (ABU) |
| Committee name | Leadership role |
| Technical committee | Chairman |

| Information and Communications Council of the Ministry of Internal Affairs and Communications |
| Committee name | Leadership role |
| ITU section |  |
| Spectrum management and planning committee | Expert member |
| Radio-wave propagation committee | Expert member |
| Satellite and scientific services committee | Expert member |
| Broadcast services committee | Expert member |
| Terrestrial wireless communications committee | Expert member |

| Telecommunication Technology Committee (TTC) |
| Committee name | Leadership role |
| Multimedia Application Working Group |  |
| IPTV-SWG | Leader |

Association of Radio Industries and Businesses (ARIB)

| Committee name | Leadership role |
| Broadcasting international standardization working group | Chairman |
| Digital broadcast systems development section | Committee chairman |
| Multiplexing working group | Manager |
| Download methods TG | Leader |
| Video coding methods working group | Manager |
| Data coding methods working group | Manager |
| Advanced data imaging (H.264) TG | Leader |
| Data broadcasting methods working group |  |
| Application control ad hoc group | Leader |
| Copyright protection working group | Manager |
| Digital receivers working group |  |
| Ultra-high-definition TV broadcast receivers TG | Leader |
| Digital satellite broadcasting working group | Manager |
| Mobile multimedia broadcasting methods working group | Manager |
| Digital terrestrial broadcasting transmission path coding working group | Manager |
| Studio facilities development section |  |
| Studio sound working group | Manager |
| Sound quality evaluation methods working group | Manager |
| Contribution transmission development section |  |
| Terrestrial wireless contribution transmission working group | Manager |
| Millimeter-wave contribution transmission TG | Leader |
| New frequency FPU study TG | Leader |

Promotion strategy committee

| Committee name | Leadership role |
| Digital broadcasting promotion sub-committee |  |
| Digital broadcasting experts group (DIBEG) |  |
| International technical assistance task force | Manager |
| Next-generation broadcast study task force assisting Japan-Brazil joint work section, etc. | Manager |

Standard assembly

| Committee name | Leadership role |
| Low power radio station working group |  |
| Radio microphone WG |  |
| New digital transmission format study TG | Leader |

7.1.2 Collaboration with overseas research facilities

High dynamic range (HDR) imaging is attracting attention globally. We participated in discussions at the HDR sub-group of the Broadcast Technology Futures (BTF) group of the European Broadcasting Union (EBU). NHK and BBC jointly proposed an HDR format compatible with the conventional standard to the ITU Radiocommunication Sector (ITU-R) and the Advanced Television Systems Committee (ATSC) 3.0. Brazil adopted Japan’s ISDB-T standard as a basis for their
digital terrestrial broadcasting in June 2006. Since then, the public and private sectors in Japan have worked together to promote ISDB-T worldwide. This effort has so far resulted in 17 foreign countries adopting ISDB-T. This year, we promoted the standard by participating in the Digital Broadcasting Experts Group (DiBEG) and International Technical Assistance Task Force of ARIB.

7.1.3 Collaborative research and cooperating institutes

In FY2015, we conducted a total of 26 collaborative research projects and 26 cooperative research projects on topics ranging from system development to materials and basic research. We collaborated with graduate schools in eight universities (Chiba University, the University of Electro-Communications, the Tokyo Institute of Technology, Tokyo Denki University, Tokyo University of Science, Toho University, Tohoku University, and Waseda University) on education and research through such activities as sending part-time lecturers and accepting trainees.

7.1.4 Visiting researchers and trainees and dispatch of STRL staff overseas

We hosted one visiting researcher from Brazil to honor our commitment to information exchange with other countries and mutual development of broadcasting technologies. As part of a program for hosting young researchers from ABU (Asia-Pacific Broadcasting Union) member institutes, we hosted one researcher from Vietnam. We also took on one post-doctoral research project (Table 1).

We provided guidance to a total of 21 trainees from six universities (the Kanagawa Institute of Technology, Tokai University, Tokyo Denki University, Tokyo City University, Tokyo University of Science, and Waseda University) in their work towards their Bachelor’s and Master’s degrees.

Four STRL researchers were dispatched to research institutions in the United States, the United Kingdom, and Canada (Table 2).

Table 1. Visiting researchers

<table>
<thead>
<tr>
<th>Type</th>
<th>Term</th>
<th>Research topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visiting researcher</td>
<td>From 2016/1/12</td>
<td>Super HI-Vision terrestrial transmission technology</td>
</tr>
<tr>
<td>ABU visiting researcher</td>
<td>From 2016/1/28</td>
<td>Super HI-Vision imaging system</td>
</tr>
<tr>
<td>Post-doctoral student</td>
<td>2012/5/1 to 2014/4/30</td>
<td>Acceptance characteristics for sensation of depth from high-resolution video</td>
</tr>
</tbody>
</table>

Table 2. Dispatch of NHK STRL researchers overseas

<table>
<thead>
<tr>
<th>Location</th>
<th>Term</th>
<th>Research topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Massachusetts Institute of Technology, USA</td>
<td>2015/9/2 to 2016/3/31</td>
<td>Interactive system and its application technology for 8K content utilization</td>
</tr>
<tr>
<td>Carnegie Mellon University, USA</td>
<td>From 2016/1/11</td>
<td>Information security</td>
</tr>
<tr>
<td>BBC, UK</td>
<td>From 2016/1/19</td>
<td>Survey and research on program production systems using telecommunications network technology</td>
</tr>
<tr>
<td>University of Calgary, Canada</td>
<td>2014/11/30 to 2015/11/27</td>
<td>Content and privacy protection for content delivery</td>
</tr>
</tbody>
</table>

7.1.5 Commissioned research

We are participating in research and development projects with national and other public facilities in order to make our research on broadcast technology more efficient and effective. In FY 2015, we took on five projects, including ones from the Ministry of Internal Affairs and Communications and NICT*.

- R&D of efficient use of frequency resource for next-generation satellite broadcasting system
- R&D of technology encouraging effective utilization of frequency for ultra-high-definition satellite and terrestrial broadcasting systems
- R&D on highly efficient frequency usage for the next-generation program contribution transmission
- Development of variable transmission capacity technology
- R&D on ultra-realistic communication technology through innovative 3D video technology
- Technologies for creating innovative 3D video displays
- Technologies for recognizing and transmitting sensitive information

* NICT: National Institute of Information and Communications Technology

7.1.6 Committee members, research advisers, guest researchers

We held two meetings of the broadcast technology research committee and received input from academic and professional committee members. We held 17 sessions to obtain input from research advisers. We also invited researchers from other organizations to work on four research topics with us.
7.2 Publication of research results

7.2.1 STRL Open House

The theme of the STRL Open House for 2015 was “Countdown to the Ultimate TV!”; the event included 26 exhibits, nine poster displays, and four interactive exhibits of the laboratories’ latest research results. The exhibits centered on 8K, for which test broadcasting is scheduled to begin in 2016, new broadcasting technology using the Internet, 3D television technology, user-friendly broadcasting technology, and advanced content production technology. The event attracted a total of 20,123 visitors. The world’s first 8K satellite broadcasting experiment was carried out, in which live video from Odaiba in Minato ward was received at the STRL in Setagaya ward through an actual broadcasting satellite. The demonstration highlighted that our development of 8K equipment, ranging from devices for content production through to home receivers, is making steady progress. The keynote speech described our R&D plan for FY 2015-2017. Lectures and research presentations introduced our R&D on 8K and future technologies to visitors.

Schedule
- May 26 (Tuesday) Opening ceremony
- May 27 (Wednesday) Open to invites
e- May 28 - June 31 (Thursday to Sunday) Open to the public
7 Research-related work

7.2.2 Overseas exhibitions

The world’s largest broadcast equipment exhibition, the National Association of Broadcasters (NAB) Show 2015, was held in April. We exhibited the latest 8K technologies, including a 350-inch theater screen, a compact 8K camera, an 8K/120-
Hz program production system and hybrid services using MPEG Media Transport (MMT). We presented our development roadmap, running from the 8K satellite broadcasting experiment in 2015 to the planned coverage of the Tokyo Olympics in 2020, and demonstrated to attendees that we are making great strides toward 8K broadcasting. The show attracted about 103,000 visitors from around the world.

In June, we transmitted video of the FIFA Women’s World Cup Canada 2015 to 8K public viewing venues in New York, Los Angeles, and Vancouver. Some of the video was screened live. At the Los Angeles venue, about 500 viewers enjoyed the excellent sense of presence offered by 8K video shown on a 350-inch theater screen.

The International Broadcasting Convention 2015 (IBC 2015), the largest broadcast equipment exhibition in Europe, was held in September. We exhibited 8K High Dynamic Range (HDR) LCD for the first time as well as other 8K technologies such as a loudness meter and MMT-based hybrid services. The convention drew about 55,000 visitors.

### Exhibitions in Japan

Throughout the year, NHK broadcasting stations all over Japan hosted exhibitions of the latest broadcast technologies resulting from our R&D. At CEATEC JAPAN 2015, we presented an 8K satellite broadcasting experiment in which 8K Super Hi-Vision content was transmitted by satellite from the NHK Broadcast Center in Shibuya to the CEATEC event site in Makuhari. We also presented at various events a new interactive exhibit device, called “Let’s Make Faces!”, that recognizes the user’s facial expressions and controls the CG.

#### Academic conferences, etc.

We presented our research results at many conferences in Japan, such as the ITE and IEICE conferences, and had papers published in international publications such as IEEE Transactions, Journal of Applied Physics, and Journal of the Society for Information Display.

#### Press releases

We issued 12 press releases on our research results and other topics.
7.2.6 **Visits, tours, and event news coverage**

To promote R&D on 8K Super Hi-Vision and integral 3D television, we held tours for people working in a variety of fields including broadcasting, movies, arts, and academic research. We welcomed visitors from around the world, including officials of standardization and international broadcasting conference organizations, such as the International Telecommunication Union (ITU) and International Broadcasting Convention (IBC), and broadcasters from various countries.

<table>
<thead>
<tr>
<th>Dates</th>
<th>Press release content</th>
</tr>
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<tbody>
<tr>
<td>2015/5/14</td>
<td>Announcement of the STRL Open House 2015 “Countdown to the Ultimate TV!” with 26 exhibits of our research results</td>
</tr>
<tr>
<td>5/14</td>
<td>World’s first public presentation of 8K Super Hi-Vision satellite broadcasting experiment</td>
</tr>
<tr>
<td>5/26</td>
<td>Successful cable TV transmission of 8K Super Hi-Vision satellite broadcasting experiment signals</td>
</tr>
<tr>
<td>5/26</td>
<td>Development of a laser-backlit direct-view LCD that supports wide color gamut</td>
</tr>
<tr>
<td>5/26</td>
<td>Development of a full-specification 8K Super Hi-Vision projector</td>
</tr>
<tr>
<td>5/26</td>
<td>Development of an “MPEG-DASH player” - For new video distribution services -</td>
</tr>
<tr>
<td>5/26</td>
<td>Increased image quality of integral 3D television – Development of a new tiling technology for displays -</td>
</tr>
</tbody>
</table>

**Inspections, tours** 90 instances (32 from overseas)

**News media** 21 events

7.2.7 **Bulletins**

We published bulletins describing our research activities and achievements on special topics such as 3D imaging, next-generation image sensors, and barrier-free broadcasting technologies for visually impaired people. The Broadcast Technology journal, which is directed at overseas readers and features in-depth articles about our latest research and trends, included such articles as “Technologies that Support Evolution of Hybridcast,” “Technologies that Support 8K Satellite Broadcasting Experiment,” and “High Dynamic Range (HDR) 8K Display Developed.”

- **Domestic Publications**
  - STRL Dayori (Japanese, monthly) No. 121 to No. 132
  - NHK STRL R&D (Japanese, bimonthly) No. 151 to No. 156
  - Annual Report (Japanese, annually) FY2014 Edition

- **Publications for overseas readers**
  - Broadcast Technology (English, quarterly) No. 60 to No. 63
  - Annual Report (English, annually) FY2014 Edition

7.2.8 **Website**

The NHK STRL website describes our laboratories and their research and posts reports and announcements on events such as the Open House and the organization’s journals. We redesigned the website so that it can be easily browsed on smartphones and tablets. To help introduce our research results, we created PR video clips and released them on the “NHK STRL Video Library” webpage.
7.3 Applications of research results

7.3.1 Cooperation with program producers

Equipment resulting from our R&D has been used in many programs. For instance, our hybrid sensor, which enables synthesis of CGs with images captured by a compact video camera, has been used at several local broadcast stations. Our millimeter-wave mobile camera system, which uses millimeter-waveband radio waves to transmit Hi-Vision video with high quality and low latency, performed well in live sports coverage of golf tournaments, etc. Our ultra-high-sensitivity Hi-Vision HARP camera captured the eyes of animals shining at night for educational programs, while our “Insect Microphone” recorded the sounds of moving insects for natural science programs. We collaborated in the production of 31 programs in FY 2015.

Use of “hybrid sensor” in virtual video production at local broadcast stations

The virtual studio needs camera parameters and other information in order to synthesize CGs with images captured with video cameras. Our hybrid sensor can autonomously measure the movements of the camera in which it is installed. It can turn an ordinary studio into a virtual studio capable of real-time synthesis of CGs and real images. The NHK Fukuoka station used this hybrid sensor to create the program, “Kin-Suta - The Road to Becoming a World Heritage Site.” Novel imaging effects, such as expressing a large space in the upper part of the studio by displaying a CG image of the sky with many photographs and presenting video in front of the cast members, helped introduce viewers to the sacred island of Okinoshima and associated sites in the Munakata Region, a candidate World Heritage Site.

7.3.2 Patents

NHK participates in the Digital Broadcasting Patent Pool, which bundles licenses of patents required by digital broadcasting standards under reasonable conditions. The pool especially promotes the use of patents held by NHK to help with the switch to digital broadcasting. We also participate in the HEVC Patent Pool for licensing the video compression technologies compliant with international standards. We are protecting the rights to our broadcasting and communications-related R&D as part of our intellectual property management efforts, and we are actively promoting transfers of patented NHK technologies using the “Technology Catalogue,” which summarizes NHK’s transferrable technologies, and at events such as the STRL Open House 2015, the “45th NHK Program Technology Exhibition” held at the NHK Broadcast Center, the “Technical Show Yokohama 2016” hosted by the City of Yokohama, and “CEATEC JAPAN 2015”.

Patents

Patents and utility model applications submitted

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<td>Designs</td>
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<tr>
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<td>107</td>
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<tr>
<td>Total</td>
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<td>1,469</td>
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Patents and utility models granted

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<td>Utility models</td>
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<td>Designs</td>
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<td>8</td>
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<td>Overseas</td>
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<td>168</td>
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<td>Total</td>
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<td>1,886</td>
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Patents and utility models in use (NHK Total)

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<td>Patents</td>
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<tr>
<td>Expertise</td>
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Technical cooperation (NHK Total)

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<tr>
<td>Technical cooperation projects</td>
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</tr>
<tr>
<td>Commissioned research projects</td>
<td>5</td>
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</tbody>
</table>

7.3.3 Prizes and degrees

In FY 2015, NHK STRL researchers received 38 prizes, including the Meritorious Award on Radio and the Takayanagi Memorial Award. Two researchers obtained doctoral degrees in FY 2015, and at the end of FY 2015, 81 STRL members held doctoral degrees.
Award Winner | Award Name | Awarded by | In recognition of | Date
--- | --- | --- | --- | ---
Masaru Takechi | ITU-Aj Award | ITU Association of Japan | Contribution as rapporteur and chair of the Rapporteur Group to the establishment of Recommendations for “Common core for declarative content format” (DCC) and “Requirements for integrated broadcast-broadband systems” (2011/2013) | 2015/6/15
Kazuhiro Iguchi | Information and Systems Society Activities Achievement Award | Institute of Electronics, Information, and Communication Engineers (IEICE) | Contribution to Image Engineering Technical Group activities | 2015/5/25
Shuhei Oda, Takeshi Kusakabe (NHK Matsuymia Station), Jun Asano (NHK Matsuymia Station) | Technology Promotion Award: Advanced Development Award (Operation Division) | Institute of Image Information and Television Engineers (IET) | Development of Remote Storage IP Transmission System for Video Signals of Disasters, Accidents and News Materials | 2015/5/29
Reconstructive video coding system development group | Technology Promotion Award: Advanced Development Award (R&D Division) | Institute of Image Information and Television Engineers (IET) | Development of a real-time ultra-high-definition video coding system using reconstructed MEMS Panel | 2015/5/29
22.2 ch multichannel sound loudspeaker frame development group | Image Information Media Future Award, Frontier Award | Institute of Image Information and Television Engineers (IET) | Development of a binaural reproduction method using the 22.2 ch multichannel sound loudspeaker frame | 2015/5/29
Super Hi-Vision interface development team | Image Information Media Future Award, Next-generation TV Technology Award | Institute of Image Information and Television Engineers (IET) | Development and standardization of 8K/4K video production system, “U-SID” | 2015/5/29
Tou Kuroda | Mentions Award on Radio presented by the Chairman of the Board of ARIB | Association of Radio Industries and Businesses (ARIB) | Contribution to R&D and practical application of broadcasting technologies in Japan | 2015/6/16
Isao Goto | AAMI Nagao Award Student Award | Asia-Pacific Association for Machine Translation | “Word Resembling for Statistical Machine Translation via Modeling Structural Differences between Languages” | 2015/6/16
Yosuke Endo | Telecommunication Technology Committee Award | Telecommunication Technology Committee | “Achievement in promotion of IPTV standardization” | 2015/6/22
Handy camera-enabled virtual studio development group | Hooz Buruka Foundation Awards, Broadcasting Technology Division | Hooz Buruka Foundation | Development and practical application of virtual studio using handy camera with compact position sensor | 2015/7/7
Hirohiko Fukagawa | Suzuk Memorial Award | Institute of Image Information and Television Engineers (IET) | Development of an atmospherically-stable ILED device and its application to flexible displays | 2015/8/27
Masato Miura | Suzuk Memorial Award | Institute of Image Information and Television Engineers (IET) | Integral three-dimensional imaging system with enhanced horizontal-vertical viewing zone by use of camera array | 2015/8/27
NHK Innovative Technologies 2015 | Ministry of Economy, Trade and Industry | Augmented TV | Contribution to the effective use of radio waves in broadcasting through R&D on a digital format capable of 10 times the size of data transmission of the European format for FM multiplex broadcasting as well as R&D and standardization of ISDB-T terrestrial digital broadcasting standard | 2015/8/27
Tsuyoshi Nakagawa | IEJ Excellent Presentation Award | Institute of Electrical Engineers of Japan (IEJ) | “The history and future of R&D on optical fiber transmission technologies at NHK STL” | 2015/9/10
Jun Goto | DOCOMO Mobile Science Prize, Award of Excellence in Advanced Technology Development | MCF Mobile Communication Fund | Research on semantic analysis technology of social text big data | 2015/9/28
Tetsuomi Ikeda | Award for Person of Cultural Merits of Tokyo Citizen, Technology Development | Tokyo Metropolitan Government | R&D for frequency migration of 700-MHz-band broadcasting systems | 2015/10/1
Nobuhiro Kinoshita, Yutaro Katoano, Tetsuhiko Murci, Nobuo Saito | ISDM 2015 Best Paper Award | ISDM (International Symposium on Optical Memory) | Outstanding contribution to the technology and progress of the optical memory field | 2015/10/7
Ken-ichiro Masaoka | IE Award | IEICE Image Engineering Technical Group | Design and development of a wide-color-gamut UHDTV | 2015/11/2
Shuhei Oda, Masaru Takechi, Akitasu Babba, Hano Hoshino (NHK Tsu station), Kazuhiro Kamitsume (Engineering Department) | Kanto Region Inven tor Award, Invention Encouragement Award | Institute of Invention and Innovation | Reliable video transmission scheme using public IP network | 2015/11/13
Masahide Karahashi, Yuki Yamamichi, Toshiyuki Nakamura (NHK Tsu station) | SETIS 2015 Best Paper Award | SETIS (Signal Image Technology & Internet Based Systems) | Real-time ball position measurement for football games based on Ball's appearance and motion features | 2015/11/24
Yuki Honda, Masakazu Niida, Kazunori Miyakawa, Misao Kubota | IDW ‘15 Best Paper Award | International Display Workshop, Institute of Image Information and Television Engineers (IET) | Presentation at IDW ‘15 international conference: “Electrostatic-focus FEAMAP Image Sensor with Silicon-Structured Spindt Type FEAMAP” | 2015/12/24
Hirohiko Fukagawa | IDW ‘15 Outstanding Poster Paper Award | International Display Workshop, Institute of Image Information and Television Engineers (IET) | Presentation at IDW ‘15 international conference: “Low operating voltage vertical organic light-emitting transistor using oriented molecular thin film” | 2015/12/24
Hiroaki Kawakita, Mihoko Uehara, Toshio Nakamura | IDW ‘15 Demonstration Award | International Display Workshop, Institute of Image Information and Television Engineers (IET) | Demonstration at IDW ‘15 international conference: “Development of a TV System Augmented Outside the TV Screen” | 2015/12/24
Yukihiko Nishida | Kenjiro Takayanagi Memorial Award | Kenjiro Takayanagi Foundation | R&D and standardization of Super Hi-Vision video format | 2016/1/20
Masafumi Nagakasa | Research Encouragement Award | ITE Technical Group on Broadcasting and Communication Technologies | Contribution to the standardization of ISDB/ITRI TR20008-13 | 2016/2/22
Daiichi Kois | Electronics Society Activities Achievement Award | Institute of Electronics, Information, and Communication Engineers (IEICE) | Contribution as leader to Magnetic Recording & Information Storage Technology Group activities | 2016/3/16
NHK STIRL | One Step on Electro-technology | Institute of Electrical Engineers of Japan (IEEJ) | Hi-Vision system | 2016/3/17
Jun Goto | Maexma Award | Tsushihinbuka Association | “R&D on anti-disaster SNS information analysis system, DisAANAA” | 2016/3/18
Kenta Takayama, Ken Iga | Maexma Award | Tsushihinbuka Association | Development of a multi-viewpoint robotics camera | 2016/3/18
Masahide Goto, Kei Hagaawa, Yoshinori Iguchi, Hiroshi Ohtake | 7th Integrated MEMS Symposium Best Paper Award | Japan Society of Applied Physics (USA), Study Group of the Integrated MEMS | Presentation at the 7th Integrated MEMS Symposium: “Prototypeing and evaluation of SOI-layered three-dimensional image sensors with pixel-parallel signal processing” | 2016/3/19
Ken-ichiro Masaoka, Yukihito Nishida | 31st Telecom System Technology Award Encouragement Award | Telecommunications Advancement Foundation | Design of Primaries for a Wide-Gamut Television COLORITY | 2016/3/28
Go Ohtake, Kazuto Ogawa | 31st Telecom System Technology Award Encouragement Award | Telecommunications Advancement Foundation | Privacy Preserving System for Integrated Broadcast-broadband Services using Attribute-Based Encryption | 2016/3/28
The NHK Science & Technology Research Laboratories (NHK STRL) is the sole research facility in Japan specializing in broadcasting technology, and as part of the public broadcaster, its role is to lead Japan in developing new broadcasting technology and contributing to a rich broadcasting culture.

### History of broadcasting development and STRL

- **1925:** Radio broadcasting begins
- **1930:** NHK Technical Research Laboratories established
- **1953:** Television broadcasting begins
- **1964:** Hi-Vision research begins
- **1966:** Satellite broadcasting research begins
- **1982:** Digital broadcasting research begins
- **1989:** BS Analog broadcasting begins
- **1991:** Analog Hi-Vision broadcasting begins
- **1995:** Super Hi-Vision research begins
- **2000:** BS Digital broadcasting begins
- **2003:** Digital terrestrial broadcasting begins
- **2006:** One-Seg service begins
- **2008:** Super Hi-Vision test broadcasting
- **2011:** Switchover to all-digital television broadcasting
- **2016:** Super Hi-Vision test broadcasting
- **2018:** Super Hi-Vision broadcasting

### NHK STRL Organization

<table>
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<tr>
<th>Division</th>
<th>Head</th>
<th>(at end of FY2015)</th>
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<tbody>
<tr>
<td>Planning &amp; Coordination Division</td>
<td>Toru Imai</td>
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<td>Integrated Broadcast-Broadband Systems Research Division</td>
<td>Tomoko Okamoto</td>
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<td>Advanced Transmission Systems Research Division</td>
<td>Tetsuo Ikeda</td>
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<td>Advanced Television Systems Research Division</td>
<td>Naoto Hayashi</td>
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<td>Human Interface Research Division</td>
<td>Masakazu Iwaki</td>
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<td>Spatial Image Research Division</td>
<td>Hiroshi Kikuchi</td>
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<td>Advanced Functional Devices Research Division</td>
<td>Tatsuki Yamaoka</td>
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<td>General Affairs Division</td>
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### STRL Open House

The STRL Open House is held every year in May to introduce our R&D to the public.

### Current research building

Completed March 2002
High-rise building: 14 floors above ground, two below ground
Mid-rise building: 6 floors above ground, two below ground
Total floor space: Approx. 46,000 m²
Includes research area: Approx. 16,000 m²
Total land area: Approx. 33,000 m²
Access to NHK STRL

Directions

- **Odakyu line, from Seijogakuen-mae station, south exit:**
  [Odakyu Bus/Tokyu Bus]
  - Shibu 24 (渋谷24) toward Shibuya Station
  - To 12 (導12) toward Todoroki-soshojo
  - Yo 06 (戸06) toward Yoga Station (weekdays only)
  - Toritsu 01 (都立01) toward Toritsu Daigaku Station, north exit

- **Tokyu Den-en-toshi line, from Yoga station:**
  [Tokyu Bus]
  - To 12(導12) toward Seijo-gakuen-mae station
  - Yo 06(戸06) toward Seijo-gakuen-mae station (weekdays only)

In all cases, get off the bus at the "NHK STRL" (NHK科学技術研究所) bus stop.

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Nippon Hoso Kyokai (NHK) Science & Technology Research Laboratories (STRL)
1-10-11 Kinuta, Setagaya-ku, Tokyo
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