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Protecting Radio Waves Utilization from Upper Atmospheric Disturbances

— Observation of the Ionosphere and Disturbance Prediction —

Introduction

Recent years have seen an increase in the use of radio-wave-based Global Navigation Satellite Systems (or GNSS, exemplified in the most-commonly used Global Positioning System, or GPS, of the US) integrated into vehicle navigation systems and cellular phones. Use of these systems is expected to continue to advance. For example, using precision GNSS for air navigation and during take-off and landing will allow for more efficient and flexible air traffic control, in turn enabling increasing numbers of flights, shortened flight times, and improved fuel economy. Similarly, applying precision GNSS to geological surveys would enable sophisticated electronic measurements even in remote locations such as inaccessible mountainous regions. We could also expect to see the production of GPS seismometers capable of recording not only ground acceleration but also ground shifts in terms of absolute distance.

Moreover, in Europe and the US, Digital Radio Mondiale (or DRM, a digital radio broadcasting system using mainly HF waves) is coming into focus as an innovative method of digital HF broadcasting and communication. This system allows near-FM quality audio and digital content to be broadcast to receiving stations even to the other side of the globe, and eliminates the need for base stations in global-scale digital communications. Thus, there are high expectations that this technology will enable the construction of low-cost systems with significantly reduced vulnerability to disasters and terrorism. Digital HF broadcasting is already in popular use in Europe and the US, and has contributed to the effective use of limited frequency resources. (http://www.drm.org)

The Effects of the Ionosphere

However, various factors cause errors in the use of HF radio waves and GNSS, primarily radio-wave propagation delay resulting from ionospheric electron-density variations associated with ionospheric disturbances at altitudes of 80–400 km.

It is impossible for us to prevent these disturbances, but we are capable of ensuring the safe use of positioning information through observation, prediction, and notification of these disturbances.

Life and Technology

Q: What is the difference between the ionosphere and the ionized layer?

A: The ionosphere was initially defined as a collection of several layers that reflect HF radio waves, and thus was given the name “ionized layer.” However, subsequent research has shown that a variety of structures and phenomena are present in these layers; it was thus concluded that these layers should be characterized more broadly, in terms analogous to those applied to the troposphere and stratosphere in the lower altitudes. Thus, “ionosphere” is now the more common term.

Under NICT’s “Research Project of Radio Propagation in the Ionosphere,” studies are underway to increase the precision of ionospheric observations and disturbance predictions, given the importance of these phenomena as described above.

Where Do the Ionospheric Disturbances Come From?

Examples of ionospheric disturbances with strong effects on radio use include plasma bubbles, daily variations in equatorial ionospheric anomalies, and ionospheric storms. A plasma bubble is a phenomenon in which a plasma hole (a region of low plasma density) appears within the ionosphere. Satellite observations have confirmed that the plasma density within such a hole may fall to one percent or lower of the density of the surrounding area. When radio waves emitted from satellites pass through these holes, they will propagate at a faster speed than that assumed in the calculations, resulting in positioning errors. This phenomenon emerges near the equator at dusk, and rapidly extends along the magnetic field lines in the north-south direction as the hole shifts toward the east. Thus, the plasma bubbles affecting Japan may be said to originate in Southeast Asia. Equatorial anomalies, on the other hand, are regions of high electron density centered around the 20 degrees north and south parallel in geomagnetic latitudes (coordinates based on the magnetic North and South Poles), and their positions and scales are known to vary significantly from day to day.

In order to detect the occurrence of these events as early as possible, we must establish networks to observe the ionosphere not only in Japan, but also in the Southeast Asia region, the source of the events affecting Japan.

Ionospheric Observation Network in Southeast Asia

Based on the need for such a network, NICT has devoted efforts to the establishment of a reliable ionospheric observation network in Southeast Asia.

Under the 1st Middle-Term Plans for the period up to 2005, we installed ionosondes (ionospheric observation instruments) in Cheng Mai and Chumpong (Thailand), Koto Taban (Indonesia), and Bac Lieu (Vietnam) and carried out observations. In addition, we plan to install an ionosonde unit in Phu Thuy, Vietnam. Plans are also underway to install GPS scintillation monitors in Phu Thuy and Hainan Island (China), and to set up magnetometers in Phuket (Thailand).

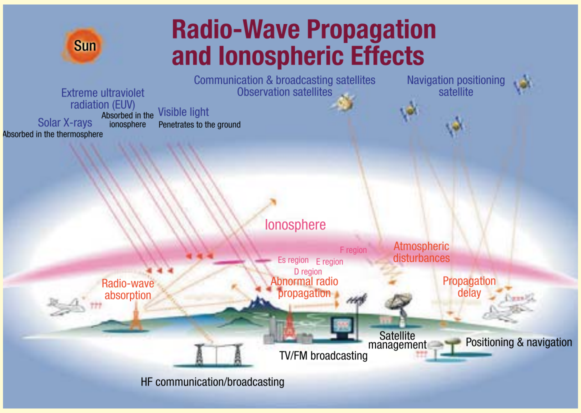
The main feature of this observation network is seen in the multiple observation stations situated on a single latitude or longitude, or positioned symmetrically relative to the geomagnetic equator. This configuration permits detailed observations on the speed and development of a disturbance event, and will allow us to make accurate predictions on the time of arrival in Japan and the magnitude of any such event. Furthermore, magnetometers installed at Phuket will be used to take measurements of the electric current flowing in the skies above the equator, providing us with useful background information on the generation of the disturbance. Through these observations, we will identify the elusive mechanism of generation of such disturbances, and will apply the knowledge gained to arrive at even greater precision in future predictions.

It is essential that the acquired data be analyzed and then swiftly publicized to the users that need this information. For such data transmission, we plan to set up communication lines using ground-based communication networks such as the JGN2 (R&D testbed network) and TEIN2 (Trans-Eurasia Information Network) and satellite communications by the planned WINDS satellite, in conjunction with efforts to overcome poor network environments in certain locations. We also intend to provide a summary of ionospheric status to Internet users, as well as to develop an automated data-distribution system that will operate via intersystem interfaces for users requiring real-time data.

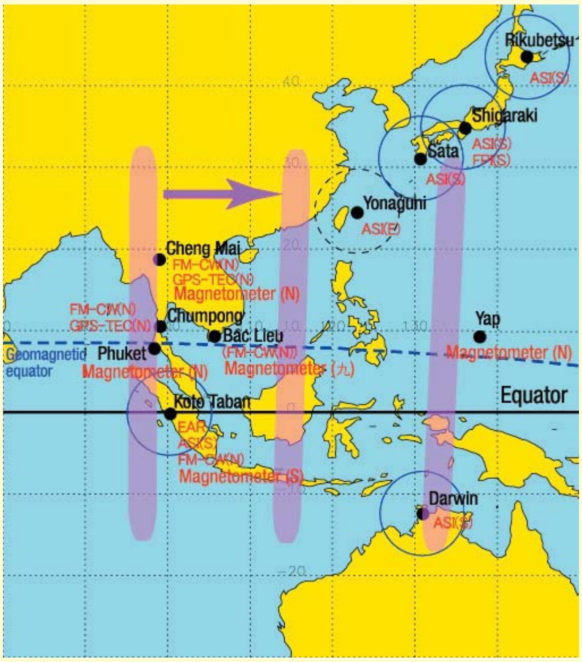
Conclusion

The presence of ionospheric disturbances is currently determined manually, based on observation data specific to each event. In the future, we believe that the process can be automated by improving the precision of automated judgment through the development of automatic data-reading technologies and knowledge-processing technologies, and that we will ultimately be capable of providing frequent, high-precision ionospheric disturbance reports.

Solar activity, while vital to our survival, is also strongly associated with the ionospheric disturbances that affect our daily lives. We are also aiming at accurate predictions of solar events and the ability to issue corresponding alerts.



How the ionosphere affect our lives in communication, broadcasting, and positioning systems



Ionospheric observation network deployed in Southeast Asia. Letters in parentheses indicate the organization responsible for management — N: NICT; E: Electronic Navigation Research Institute; S: Solar-Terrestrial Environment Laboratory, Nagoya University; "九": Kyushu University.

This month's key concept

[Ionosphere]

The Earth's atmosphere becomes thinner at higher altitudes. When ultraviolet rays (extreme ultraviolet radiation having high energy) from the Sun enter such thin layers, electrons are ejected from atoms, creating ions. This effect is known as ionization, and the resultant gas — formed of electrons and ions — is called plasma. The ionosphere is a region in which high concentrations of atmosphere in the plasma state are observed. The ionosphere surrounding the Earth has a significant impact on the propagation of radio waves used in communication and broadcasting systems, and strongly affects our daily lives — as seen, for example, in the adverse effects on the precision of GPS positioning.

Researcher

Mamoru Ishii
Research Manager for the "Research Project of the Problems in Radio Propagation in the Ionosphere"
Space Environment Group
Applied Electromagnetic Research Center, Research Department 3

After completing his graduate course, he joined the Communications Research Laboratory (currently NICT) in 1994, where he presently serves as Research Manager.

Do You Know This Facility at NICT?

NICT has a variety of experimental instruments and facilities that are essential to our research activities. In this series, we will introduce some of these unique instruments and facilities.

A Facility to Distribute Japanese Time

— The Hagane-yama Standard Time and Frequency Radio Station —

A facility that distributes time for Japan

Advanced IT societies require increasingly precise time information that is accessible throughout society. Some typical examples include transactions in electronic commerce and issuance of electronic medical charts. And precise standard time information is also required for radio clocks, the use of which has now spread to general households and individuals.

In developed countries, standards for time, frequency, and time-related information are defined by the standardization organization of the respective nation, and are provided to society through various methods of dissemination. In Japan, NICT is in charge of creating Japan Standard Time (JST) and frequency standards, and is responsible for a service to supply radio signals (collectively known as the “standard time and frequency signal”) from a low-frequency frequency standard radio station (call letters: JJY). All of the rapidly increasing number of radio clocks in Japan use this standard signal as their reference, which may easily be viewed as an essential element of the modern social infrastructure.

The time information superposed on the standard-frequency and time-signal waves are designed to maintain precise synchronism with JST created at NICT Headquarters in Koganei City, Tokyo, and this synchronization is accurate to within 10 ms relative to coordinated universal time (JST is nine hours ahead of coordinated universal time). The precision of frequency is also extremely high, at 1 x 10-12. Transmission is managed by a double-station system consisting of the Ootakadoya-yama Standard Time and Frequency Radio Station (Miyakoji-machi, Tamura City, Fukushima Prefecture) and the Hagane-yama Standard Time and Frequency Radio Station (Fuji-machi, Saga City, Saga Prefecture). Both stations perform continuous, round-the-clock transmission of radio waves at 40 kHz and 60 kHz. Of the advanced countries having low-frequency transmission facilities for standard-frequency and time-signal waves, only Japan’s NICT disseminates signals with the adoption of a mutual back-up system consisting of two stations.

In this issue, we will introduce the Hagane-yama Standard Time and Frequency Radio Station, which we visited during its regular annual maintenance and inspection of the facility.

Top: Entrance gate to the facilities of the Hagane-yama Standard Time and Frequency Radio Station; the pillar on the left is the base of the 200-m antenna.
Bottom: Low-frequency, standard time and frequency signal transmission 200-m antenna atop the 900-meter-high Hagane-yama summit; the top of the antenna is hidden in the clouds.

Standard Time Transmission Function

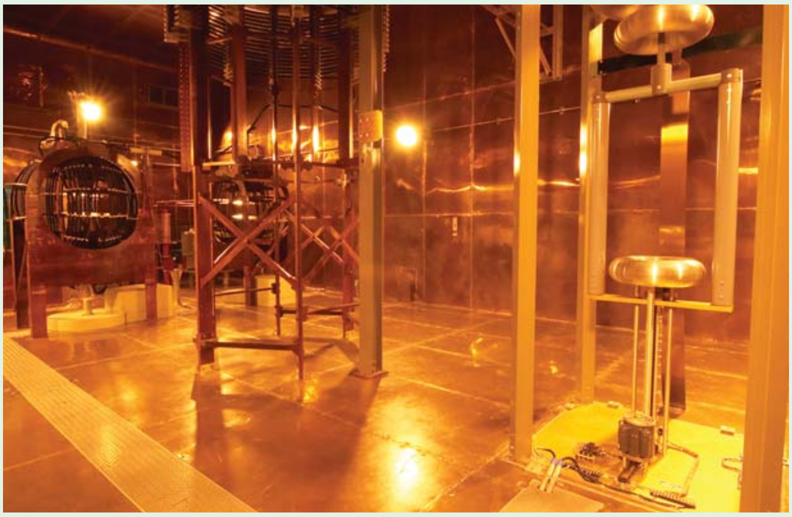
The Hagane-yama Standard Time and Frequency Radio Station is located at the border of Saga and Fukuoka prefectures. The facility is equipped with an umbrella-shaped antenna rising 200 m off the ground near the summit of Hagane-yama (altitude of approx. 900 m). The facility has a grand view of the Genkainada, and except for the lofty antenna, it appears to be a normal building. However, the entire building is covered with a special metal shield to keep the facility protected from the radio waves it emits. The service area of the standard time and frequency signal waves covers a concentric circle having a 1,000-km radius. Operation of the facility began in October 2001 with the aim of improving signal reception in western Japan, including the Okinawa Island chain.

The facility consists mainly of four blocks: the primary standard room, the time-signal management room, the transmitter room, and the converter room.

In the primary standard room, which is electromagnetically and magnetically shielded, three sophisticated cesium atomic clocks are installed. The primary standard room is normally off-limits, and the temperature and humidity of the room are strictly controlled behind doors resembling those for bank vaults. In the time-signal management room, LF frequency signals and the time code that serves as the standard signal for radio clocks are generated using the standard signal of a cesium atomic clock. In the same room, automatic control of various measuring instruments within the facility, acquisition of measurement data, and image monitoring are carried out. Moreover, satellite-assisted time comparisons are also performed to confirm on a continual basis that any deviation of time code relative to the JST created at NICT Headquarters is below the stipulated value. (The atomic clock is adjusted to accuracy within 100 ns so that the deviation of the signal ultimately transmitted from JST remains below 10 μs.)

In the transmitter room, there are two 50-kW high-power transmitters for operational and backup use, and the transmitted signals are amplified to 50 kW (using a semiconductor FET amplifier, 48-board synthesis) before being sent to the converter.

The most unique block within the facility is this converter room, with all of its inside walls and floors shielded from the outside by copper plates. This is a special room that may only be entered when transmission is not in progress. The converter installed within the room performs the impedance matching of the transmitter and the transmission antenna, and the copper shield prevents radio waves from being radiated from parts other than the antenna. The large, silver, lightning arrester rings and ball gaps, in addition to the huge coils and various instruments — some as big as a person — might even be said to be a bit ominous, are illuminated in the copper-brown room.



Converter room: large variable coil for impedance matching (left), large fixed coil (center), and drive unit for connecting the antenna to the earth (right)

According to one of the staff members, "the environment inside the converter room during transmission is the same as you'd find inside a giant microwave oven."

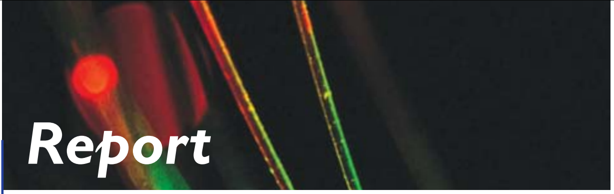
The performance of the earth connection is also important in improving the efficiency of radio-wave transmission from the antenna. Accordingly, 360 earth copper lines 4-mm in diameter each are buried in the antenna's underground foundation at 1-degree intervals from the center of the antenna. The radius of the earth lines stretches nearly 150 meters from the antenna (with a total length of 55,000 meters). Our visit was an extremely short one during a pause in transmission, but we learned from the staff that Hagane-yama experiences rough weather conditions, with frequent ground discharges of lightning. In fact, they had just experienced one only a few days prior to our visit. It's not hard to imagine the weight of responsibility they must feel to keep the facility operating smoothly.

Left/ Large coil and condenser for impedance matching
Right/ Converter room: The final block, which feeds the 50-kW transmission power from the converter room to the antenna. The doughnut-shaped metal structures forming a dumpling shape installed to the system act as a lightning arrester.

An Era Demanding Increasingly Precise JST

Japan Standard Time, which is sent to all parts of Japan on a standard time and frequency signal wave, is currently used in a wide variety of applications — radio clocks, home appliances, in-vehicle clocks, seismometers, and more. These uses are enhancing the importance of the standard time and frequency signal wave, as a sort of "lighthouse of radio waves" that carries official time in Japan. The Hagane-yama Standard Time and Frequency Radio Station, one of two such "lighthouses" in Japan supporting standard signal transmissions and ensuring the stable reception of signals in western Japan, will most likely come to be recognized as an essential part of the 21st-century social infrastructure.

Left/ Transmitter room: Two 50-kW transmitters for operation and backup use; in the event of malfunction, the system will automatically switch to the backup unit.
Right/ Time signal management block: Series of measurement machine racks for generating frequency signals and the time code for radio clocks and time comparison using the standard signal of a cesium atomic clock



Report on the 2nd Symposium on International Standardization Activities for Young Scientists

Mitsugu Ohkawa, Senior Researcher, Standardization Promotion Group, Research Promotion Department

The Standardization Promotion Group of the Research Promotion Department of NICT held the 2nd Symposium on International Standardization Activities for Young Scientists on Sept. 27, 2006, at the Toranomon Pastoral, Tokyo, Japan.

The procurement on the basis of international standards is essential to the development of ICT technology and industries in Japan. However, standardization activities require some decidedly brick-and-mortar efforts, including continual attendance at international meetings to make proposals and coordinative negotiations. And if proposals are to be accepted, not only does the content count, but those that present them must know how to take action in meetings and must be skilled negotiators.

Recently we have seen a drop in the participation of veteran researchers at international meetings; as a result, the knowledge and techniques required to hold these meetings are not being successfully passed on to the next generation. Further, more and more young scientists are attending international meetings on their own, presenting us with the urgent issue of improving their readiness to overcome the difficulties that may arise.

In order to support the international standardization activities of these young scientists, our group held a Symposium on International Standardization Activities for Young Scientists in April, in hopes of promoting exchanges between scientists from different organizations.

We invited two speakers who are active participants in two international standardization meetings with quite different nature—the ITU-R (International Telecommunications Union - Radiocommunications Sector) and IETF (Internet Engineering Task Force).

Before their lectures, we first had Mr. Ueno, Executive Director of the Research Promotion Department, report on the state of young scientists' participation in international standardization activities and also introduce NICT's efforts associated with international standardization.

Next, we had Mr. Junji Kumada, Controller of the Transmission Network Department of NHK Integrated Technology Inc., give a lecture entitled "International Standardization of HDTV." A brief summary was given on the approximately 30 years required for standardization activities for HDTV since the beginning of research and development, with a description of the various difficulties and challenges encountered during this time. This was followed by a lecture on "Efforts in International Standardization Activities for GMPLS," by Dr. Tomohiro Ohtani, Senior Manager of the Integrated Core Networking Control and Management lab. of KDDI R&D Laboratories Inc, in which he described the activities at the IETF in detail with regard to the standardization of network routing technologies.

The meeting was a great success, with approximately 80 people in attendance—nearly the maximum capacity of the venue. A party following the lecture session offered the young scientists the opportunity to talk with the veterans of standardization activities. The party was also well attended. The party opened with a speech from Mr. Inada, NICT's Vice President, and participants discussed subjects not addressed in lectures, such as behind-the-scene developments in international standardization activities.

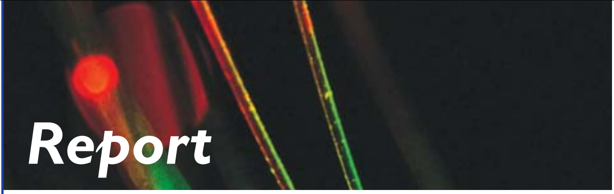
We enjoyed a favorable response according to the questionnaires completed after the lectures. Most of the young scientists found the meeting a helpful contribution to international standardization activities, reporting that they look forward to similar meetings in the future. Some requests for future lectures included discussion on how to develop the skills needed in international standardization and on international standardization activities at the IEEE. Our group plans to hold this meeting on a regular basis, and will keep the results of the questionnaires in mind when we plan future meetings.

Mr. Ueno, Executive Director of the Research Promotion Department, explaining our efforts to support international standardization

A scene from the meeting

Party for discussion among veterans and young scientists

2nd Symposium on International Standardization Activities for Young Scientists
Date: Sept. 27, 2006
Venue: Toranomon Pastoral (Tokyo)



Dissemination of IPv6 Multicast Technology for Video Transmission

— An Example of Demonstrative Experiment by Utilizing the JGN2 Testbed Network —

Hiroki Ono, Network Testbed Group, Collaborative Research Department, NICT

At NICT's Chugoku Research Center, we are carrying out demonstrative experiments for video transmission by utilizing the IPv6 multicast technology, a next-generation Internet technology using the JGN2 network and the existing R&D testbed network managed and operated by NICT. This attempt aims to achieve a certain video transmission in higher quality as well as to make IPv6 multicast technology applicable to an average network environment. In the present research, we carried out demonstrative experiments for video distribution, and other services to a common household, which are successfully confirmed to be provided by using IPv6 multicast technology. The experiment summary is shown below, while describing some of the results in the past demonstrative experiments.

Demonstrative Experiment Performed in Cooperation with a Common Household (Oct. 10–20, 2006)

Utilizing the JGN2 network, we distributed five video channels for the tourist information available on the Okayama Information Highway, which is a regional information network operated by Okayama Prefecture, via the Kagamino FTTH network as optical fiber for household use. The content was delivered to common households in Kagamino-cho and to a virtual household on a PC, which simulated the environment of a common home. In the experiment, users were switched between channels under viewing conditions assumed, in order to assess the load on the network.

Since the plans for the present experiment required an environment more closely resembling a common home, we requested the cooperation by an actual household. As a result, we were able to confirm that even in actual network environments, the IPv6 multicast technology will be able to provide video distribution services to the common household.

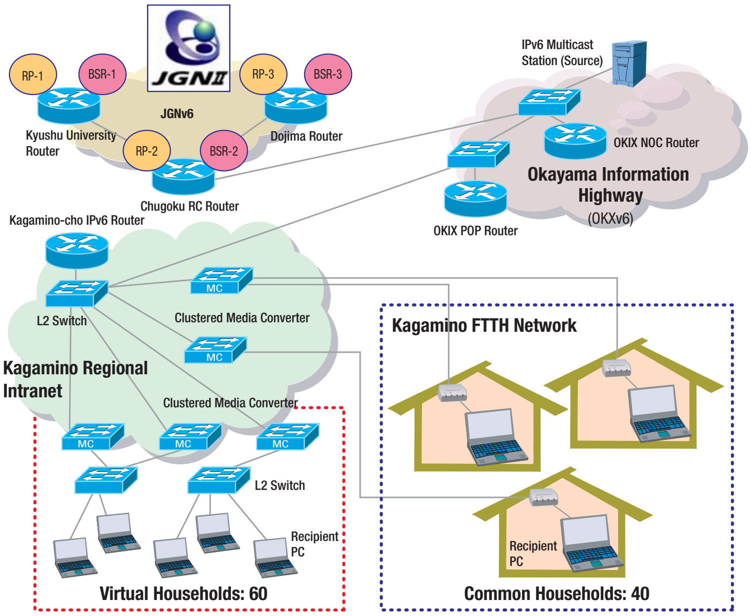
Examples of the Past Demonstrative Experiments for IPv6 Multicast Technology

In October, 2005, we conducted an experiment by taking video of the 60th National Sports Festival in Okayama at more than 20 venues in Okayama Prefecture, followed by simultaneously distributing the video to JGN2 access points all over Japan via the Okayama Information Highway. Through that experiment, we were able to verify the system connectivity to regional networks.

Then, in February 2006, we conducted an experiment to transmit live images of the Sapporo Snow Festival as well as the video contents for TV by utilizing the JGN2 testbed network through connections among Sapporo Odori Park, professional baseball training camps, Okinawa and Kochi, and six broadcasting stations in Japan, while extending to sites in Singapore, Thailand, and Korea. This experiment proved that the system is capable of integrating the broadcasting business.

Live Broadcasting of the Sapporo Snow Festival in the Video Distribution Experiment

Scheme of the Experiment



Future Prospects

We will apply the know-how gained through the various demonstrative experiments carried out until now, and will link the system to the existing networks like the FTTH network as optical fiber network for household use in order to create an effective tool for obtaining regional information for the measures of disaster prevention, crime prevention, etc. in the daily life. We will plan to carry out further demonstrative experiments while hoping to establish the IPv6 multicast technology as a next-generation Internet technology.

Report

Introduction to International Cooperation at NICT (Technological Training Program)

Kenji Tanaka, Senior Researcher, International Alliance Group, Research Promotion Department

The International Alliance Group of NICT is promoting a program to increase international cooperation through a technological training program for foreign staff and technicians affiliated with various information and communication agencies and who are currently visiting Japan through programs offered by the JICA (Japan International Cooperation Agency) and the APT (Asia Pacific Telecommunity). The themes of the training program will include introductions to the various research and development activities at NICT, from regular duties such as standard time dissemination and type approval / calibration of wireless equipment to basic and applied research (state-of-the-art optical transmission instruments and diverse wireless communication methods, language processing, communication systems for large-scale disasters, etc.). We hope that this program will help increase awareness and dissemination of technology among the participants, as well as to promote NICT's activities in general.

The training programs are mostly short; an entire visit may last only half a day at NICT, although some activities last as long as a week, such as those designed to introduce trends in the most advanced R&D activities at NICT.

NICT's technological training programs targeting increased international cooperation already have a decade or longer of history behind them. The CRL, our predecessor, proposed the establishment of an APII (Asia Pacific Information Infrastructure) Technology Center that would serve as the base station for a project to construct the APII at the 14th APEC-TEL (Asia-Pacific Economic Cooperation - Telecommunications & Information Working Group) meeting held in Taipei in July 1996. In February of the following year, the APII Technology Center opened in Kobe. Since then, 17 APT technology training programs, lasting for one week each, have been held at the center (during the period from Feb. 1997 to Feb. 2006), with 154 trainees accepted to date.

During the Feb. 2006 APT training session, we introduced policies for the latest research project—the Asia broadband project—and those for IP address management, and also included a live high-definition television broadcast from Holland. We also had participants report on and discuss among themselves the current state of IT-related environments in their own countries. A report on this training session has been presented as one of the results of activities at the APII Technology Center, in the course of the semi-annual APEC-TEL meeting.

This year, a technological training program is also planned for the one-week period beginning on Feb. 5, 2007. This session will include 20 participants from 10 different countries. The diversity of backgrounds is sometimes challenging—for example, when attempting to accommodate differences in eating habits and cultures—but the benefits of the training and discussions are well worth the difficulties. NICT plans to continue its efforts in similar activities to promote international cooperation in the future.

APT trainees for the Feb. 2006 session

Trainees and staff at the Feb. 2006 session

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