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NICT NEWS

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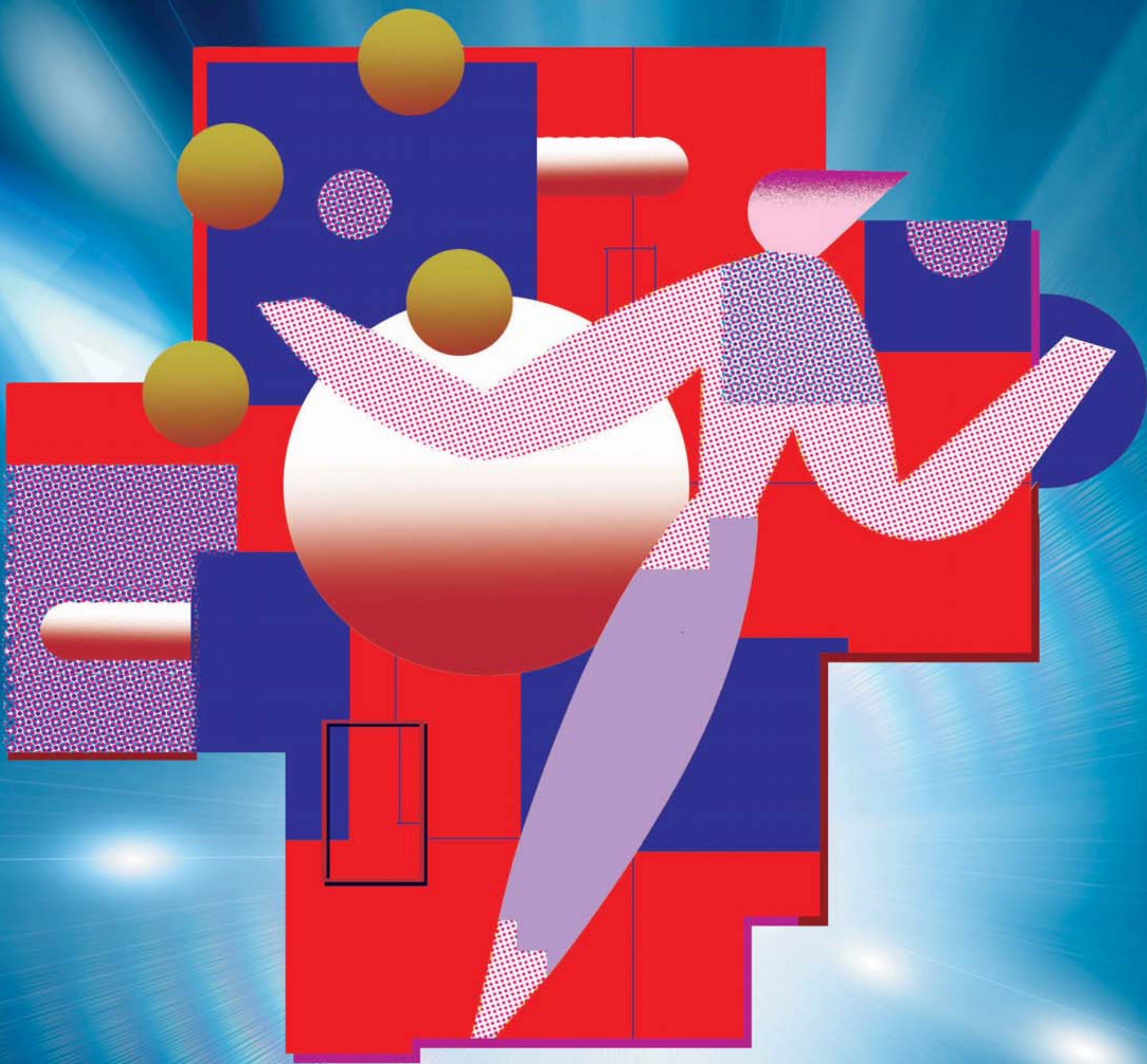

2005 DEC. 《No.357》

Discover the Seeds of New Technologies in Life

— R&D into Bio-Communications Technologies —

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Kansai Advanced Research Center,
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Ph.D. in science. Completed doctoral course at Graduate School of Science, University of Tokyo, in 1988. Joined CRL (currently NICT) in 1993. Works on single-molecule measurement of protein motors and applied research. Visiting Professor at University of Hyogo. Received 23rd Osaka Science Prize in 2005.

Life is a treasure-chest of knowledge and technologies

There is a very beautiful glass sponge, a deep sea animal known as the "Venus flower basket." It has a basket-like structure made of silica fibers that are produced by its cells. Each basket holds a pair of shrimp, who nest there for life together; in Japan this has become a metaphor for a devoted couple. When observed in cross section, this silica fiber was found to be identical to an optical fiber in structure: "its central core, made of silicic acid, is enveloped by a cladding" (Sundar et al., Nature 424, 899; 2003). In other words, this glass sponge has the property of a single-mode or multimode light guide. Its laminated structure, bonded by organic substances, is resistant to cracks. Moreover, it is possible that the optical properties of this fiber (produced by the cells at ordinary temperatures) can be easily altered by adding impurities. This merits attention as a method of synthesis that we can learn from living organisms. In another example of such synthesis, a certain species of fly is able to determine the direction of a sound source with an accuracy of 2° or less, using ears (eardrums, in fact) that are only 0.5 mm apart. The differential in the arrival time of a sound between them is only 50 ns. By accumulating differential information such as the phase difference in receptor potentials, this fly can detect position with extremely high accuracy (Mason et al., Nature 410, 686-690; 2001). This technique can be applied for information-processing in the production of micro- and nano-sensors. Life holds a wealth of such amazing abilities. I hope that you also see the fascination of research into the mechanisms and activities of living organisms.

Research into protein as a material

Proteins form one of the main research subjects of our group. Many people associate protein with food that is soft, or perishable. Is protein really a soft or weak substance? For example, a cobweb is made of protein. Its thread is as thin as 5 to 10 μm, but is comparable to a steel wire in tensile strength. If this thread were 1 mm in diameter, a person could easily hang from it. Despite this strength, the spider's thread is flexible. Likewise, many bio-based materials are both strong and flexible. Young's modulus of actin, a globular protein present in large quantities in muscles, is 2.3 GPa—comparable to that of polypropylene, a rigid plastic material. Protein, dozens of nanometers in size, is an inhomogeneous substance consisting of several hundred thousand to millions of atoms. Each one of the molecules has a function related to vital activities. Protein is thus an exceptionally interesting research subject in terms of the study of nanoscale materials.

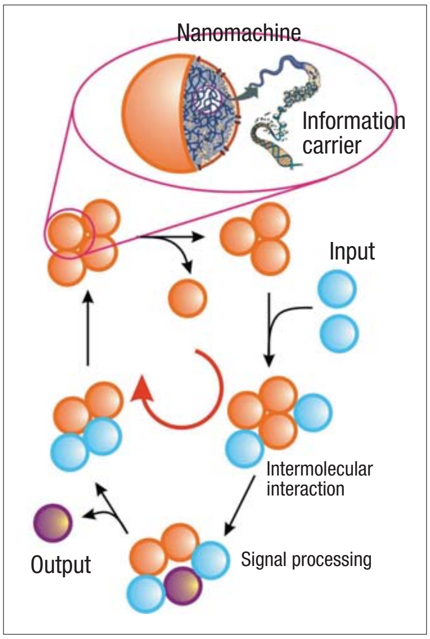
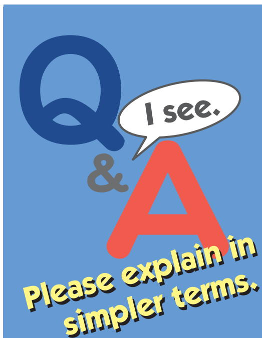


Figure 1: Molecular communications technology using bio-molecules as information carriers

Mechanisms of life

Life has an enormous amount of amazing protein-based mechanisms—for example, the self-replication, self-organization, flexibility, and plasticity found at the individual, cellular, and bio-molecular



Q What is Young's modulus? According to this article, Young's modulus of actin is 2.3 GPa. How does this compare with that of other materials?

A Young's modulus is a measure of stiffness defined by British physicist Thomas Young (1773–1829). It is determined from the relationship between elongation and stress when a substance is stretched. Each substance has an inherent Young's modulus value. For example, Young's moduli of steel, copper, and gold are 206 GPa, 130 GPa and 78 GPa, respectively. GPa is pronounced "gigapascal."

Q What is dynein?

A Dynein is a type of "protein motor" that produces movements in living organisms. Dynein is known as the motor responsible for the movements of flagella and cilia. Another type of protein motor transports various substances within a cell. Apart from dynein, important protein motors include "myosin," which is responsible for the contraction of skeletal muscles, and "kinesin," which is involved in the transportation of substances within a cell.

levels, as well as living organisms' high energy-conversion efficiency. These mechanisms are so amazing that it is not yet possible to emulate them artificially. However, when we do succeed in applying them in synthetic ways, each of these capabilities will be of significant benefit to humankind. It would be a shame to ignore the new technologies we can gain from life.

Our bodies contain an organelle referred to as a "cilium" (plural: cilia), which is a whip-like organ one-thousandth the thickness of a human hair (about 200 nm) and 20 μm in length. Cilia are present in large numbers and undulate as a whole at dozens of hertz to propagate waves that carry small particles and liquids. The type of protein responsible for this cilium movement is called "dynein." We discovered that dyneins change their conformations in a unique cycle. A bend formed in a cilium gradually moves to its tip without attenuation. This phenomenon means that a high-motor-activity area moves through the dyneins in the cilium in an orderly manner. However, the dyneins do not electrically communicate with one another, nor are their movements controlled centrally. Based on information carried by force, the individual dyneins autonomously change their conformations to create an entire system of cilium movement. Similarly, silicon devices in a computer do not interact with one another, except when they are faulty. Using such weak interactions, bio-devices function in an autonomous and self-organized manner. Simple changes in the structure of individual dynein molecules are combined, and adjacent dyneins pass information between each other to form a network. In this way, the dyneins autonomously create a unified and complex movement (specifically, an undulation) of the cilium. This amazing bio-system embodies both networking and a hierarchy of device functions. Dynein is a perfect subject of research in our search to devise network algorithms for use in ICT.

Molecular communications

The Protein Biophysics Group has begun development of molecular communications technologies to create an autonomous and flexible nanoscale network, with effective use of the above-mentioned interactions among bio-molecules and cells where molecules and forces serve as information carriers. We are conducting this project in collaboration with a research group led by Professor Suda of the University of California at Irvine, an institution well known for its leading-edge research in information science. Molecular communications is now receiving worldwide attention as a research field in which biology, nanoscience, and ICT can be integrated.

In a living organism, the transfer of a substance is a transfer of information. For example, molecular communications take place as a transfer of substances and a series of biochemical molecular reactions induced by this transfer (such as homeostasis by means of hormones and intracellular signal transduction). The high degree of specificity of bio-molecules and cells contributes to an increase in the sensitivity of the system. Weak interactions ensure flexibility in handling environmental information. Through direct use of the autonomous and self-organizing functions of cells and bio-molecules, and the extraction of algorithms from these functions, we can propose challenging tasks for biology and information science, which in turn may lead to amazing insights and discoveries.

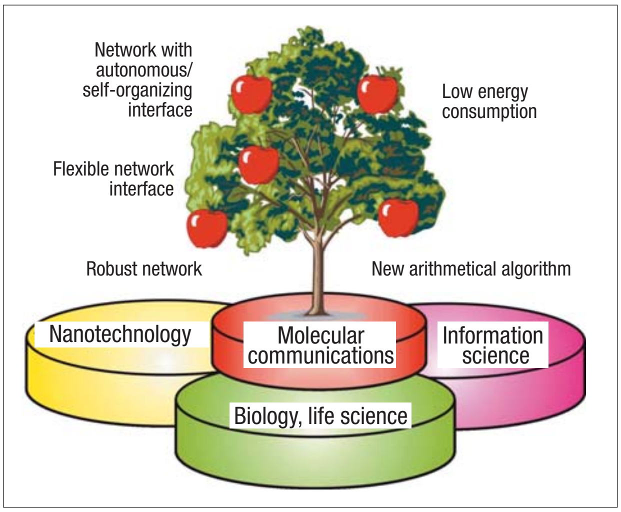


Figure 2: **Molecular communications opens up a new dimension for ICT through integration of information science, biology, and nanotechnology**

Conclusion

Just about a century ago, the Wright brothers succeeded in powered flight for the first time in the world. What percentage of people of that time imagined that jumbo jets would be flying in the sky 100 years later? The history of silicon dates back to the Stone Age, when humankind first began to use flint. Eighty years ago this substance was identified as an element, and 40 years have elapsed since we successfully generated a single silicon crystal artificially. This accumulation of knowledge has led to the proliferation of silicon technologies today. On the other hand, the structure of a protein crystal was analyzed for the first time in 1960. Due to vigorous efforts devoted since to various structural and functional analyses, protein science is now advancing rapidly as a branch of the life sciences. I believe that now is the time to begin our research into the use of protein as a functional material.

[Postscript]

The other day, I received the 23rd Osaka Science Prize. I owe this honor to my colleagues and to the valuable research environment offered by NICT.

Life & Technology

● Potential of protein for use as ultra-small information processing device

The results of our research to date include observation of a single dynein molecule and control of protein motor movements using a pattern created on a substrate. It is now considered possible to create a "molecular vehicle" weighing 10 to the -17th gram (0.00000000000000001g) by combining various protein molecules, and to load and unload information to and from this vehicle for use in communications. We can also envision the manufacture of a bio-chip for a highly advanced information-processing and physical distribution system. This 1-cm-square chip will be comparable in capacity to all land traffic and physical distribution systems across the country.

e-VLBI R&D

— Interaction Between Science and Next-Generation High-Speed Network Technology —

Yasuhiro Koyama

Leader of Radio Astronomy Applications Group, Kashima Space Research Center, Applied Research and Standards Department

Ph.D. Engaged in research into geophysics and radio science at Kashima Space Research Center (formerly CRL's Kashima Branch) since 1988. Directing Board member of the International VLBI Service for Geodesy and Astrometry since 2001.

Introduction

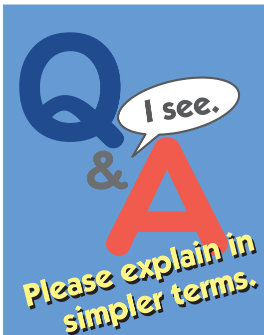
Today the use of network technology is expanding rapidly. Historically, network technology was developed partly due to the needs of scientists who were engaged in basic research in the fields of high-energy physics, astronomy, and similar areas. For example, the worldwide web was devised for the exchange of information among researchers in high-energy physics. In 1987, researchers around the world communicated with one another by email when they used various techniques to observe a supernova explosion in the Large Magellanic Cloud. Since it is now possible for researchers around the world to share information—including observation data and analysis results—R&D activities are now conducted at a much faster pace than in the past, when these networks were not available. To perform the e-VLBI that I will describe in this article, it is necessary to perform high-speed transmission of an unprecedented amount of data over an extremely long distance, which presents a new challenge to network technology research as well. In this sense, the network is not merely used as a means to facilitate e-VLBI, but plays a critical role in bringing about new findings, thus e-VLBI is a subject that epitomizes the interaction between scientific and network-technology research.

Achievements in e-VLBI research to date

When used in radio astronomical observation, VLBI delivers much higher resolution than observation techniques in other wavelength bands such as visible and infrared rays. In geophysics, VLBI is the most precise means to measure terrestrial and celestial reference frames and the direction of the Earth's rotation axis, or the "Earth's orientation," which changes irregularly. When the relevant data processing is performed speedily through the use of e-VLBI, it will become possible to measure the Earth's orientation at a given moment with high accuracy. This will enable accurate positioning of satellite orbits, which in turn will lead to an increase in the accuracy and reliability of satellite-based positioning. In the field of astronomical research, e-VLBI is expected to increase the sensitivity of observation to a significant extent, enabling observation of faint objects that were previously unobservable. The sensitivity of VLBI increases in proportion to the data rate. If magnetic tapes are used, the maximum data rate is 1 Gbps. However, if data processing is performed in real time through a network, observations will take place at significantly higher data rates.

In 1997, we used a dedicated network to perform e-VLBI for the first time in the word, through a joint research initiative with NTT. Later, we developed an e-VLBI observation network featuring a data rate of 2 Gbps through joint research with the National Astronomical Observatory of Japan and the Geographical Survey Institute. However, to perform e-VLBI observation on an international scale, an IP-based shared network is required. Accordingly,

Figure 1: 34-meter antenna at Kashima Space Research Center



Q What is e-VLBI?

A VLBI stands for "very long baseline interferometry." In interferometry, several antennas are used to receive radio waves from an astronomical object at the same time, and then the obtained signal data is combined. By recording the signal data along with accurate timing information for later analysis, VLBI makes it possible for researchers to set up the antennas at any distance from one another. However, since the data is stored on magnetic tapes, it takes at least a week to collate the observation results (mainly because of the time required to transport the tapes). In contrast, e-VLBI enables analysis in quasi-real time by sending the data through a high-speed network.

Q What kind of method is used to combine observation data?

A The method used to combine observation data received by several antennas is called "correlation processing," which basically consists of high-speed processing of cross-correlation functions. Conventionally, a dedicated device referred to as a "correlator" has been used to perform this processing, which must function at extremely high speeds. Today, with a view to greater processing capability and scalability, significant attention is being devoted to the development of a software correlator that can perform processing using PCs distributed over a network. NICT has been working on the development of a software correlator that is now used by research institutions in Japan and eight other countries.

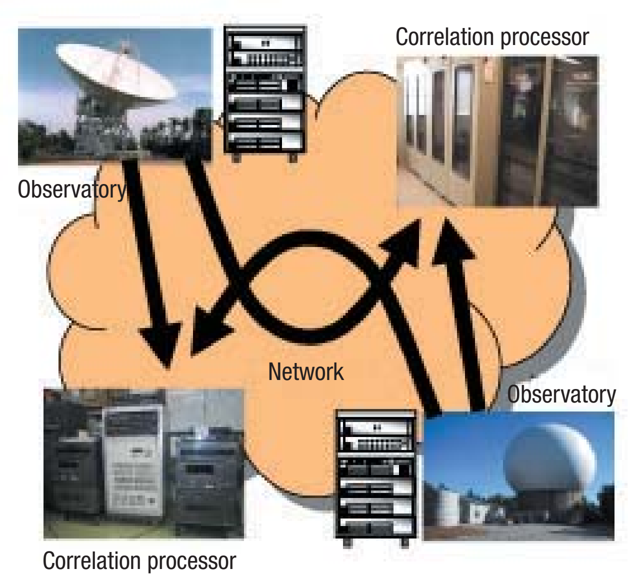


Figure 2: **Conceptual drawing of e-VLBI**

we began development of the K5 observation system in 2001. e-VLBI has already been adopted in part by international VLBI observation projects and is used to perform regular observations. In June 2004, we worked with the MIT Haystack Observatory to perform observations lasting for about an hour and succeeded in determining UT1, one of several Earth-orientation parameters, within four and a half hours. In addition, we are conducting active research on the precise positioning of scientific exploration satellites and precise control of space probes, also using e-VLBI.

Goals for the future

As an immediate goal, we hope to establish a technology to perform efficient, real-time data transmission over long distances within an IP-based shared network environment. We are also working on high-speed correlation processing using many PCs distributed over this network. We are also developing the ADS3000, a data sampling/high-speed processor for use in observation systems (Figure 3). The ADS3000 is designed to perform A/D conversion at a sampling rate of up to 2 GHz and a quantization bit rate of 8, and to output observation data that has gone through digital-filtering and frequency-conversion processing using an FPGA (a type of high-speed programmable chip). With the world's highest sampling rate of 2 GHz, the ADS3000 is expected to increase the sensitivity of observation and to enable more flexible observation modes. Additionally, this processor has the potential for a wide range of uses in the scientific observation and research fields—for example, it is increasingly being used in spectrometers.

Figure 3:
The ADS3000 data sampling/high-speed processor

Conclusion

VLBI observation was made possible only by the combination of various technologies—from radio receiving technologies to frequency-standard and data processing techniques. We have been carrying out joint and commissioned research activities with the Geographical Survey Institute and many other research institutes and universities that have adopted the VLBI observation and processing system developed by NICT. Our current work on e-VLBI is opening up an enormous number of possibilities thanks to the highly advanced nature of the network and other communications technologies involved. In this respect, NICT has gained outstanding expertise both in information communications and radio-wave measurement, which allows us to carry out uniquely effective R&D. At the international level, the International VLBI Service for Geodesy and Astrometry (IVS) was established in 2000 to pursue technological development and observation through collaboration among research institutes in many countries. The IVS formulated the "VLBI2010," a vision of future VLBI to be realized by 2010. With a view to making the VLBI2010 vision reality, we will continue to develop a range of useful technologies centering on e-VLBI.

Life & Technology

● Kashima Space Research Center as the base for Japan's new latitude-longitude system

With enforcement of the amended Survey Act in 2002, Japan's geodetic reference system shifted from Tokyo Datum (a local system) to the World Geodetic System. Under the new system, the latitudes and longitudes of triangulation station points in Japan were recalculated based on the position of KSRC's 26-meter antenna. This antenna was selected because it had been used in a number of international VLBI observation projects and its precise position had been measured based on numerous observation results. VLBI ensures the accuracy of the positional information now in wide use in automobile navigation systems. Ownership of this 26-m antenna was transferred to the Geographical Survey Institute in 1992 and the antenna was used in VLBI observation and similar applications until 2003.

International Alliance Division, Strategic Planning Department
Public Relations Division, General Affairs Department

Report on Participation in World Summit on the Information Society (WSIS)

The World Summit on the Information Society (WSIS) took place in Tunis, the capital of Tunisia, from November 16 through 18, 2005. The United Nations (UN) and the International Telecommunication Union (ITU) hosted this large-scale international conference, which was attended by 23,000 people from 174 countries (nearly all of the UN member states). The main attendees included UN Secretary-General Kofi Annan, ITU Secretary-General Yoshio Utsumi, and Japanese Internal Affairs and Communications Minister Heizo Takenaka, who made a statement at the summit plenary session. At the summit, the Japanese Internal Affairs and Communications Ministry organized a workshop under the theme "Toward the Realization of a Ubiquitous Network Society."

In parallel with this summit conference, an exhibition was held at the same site from November 15 through 19. The main topics of the exhibition included e-strategies, measures against the so-called "digital divide," and the promotion of partnerships. There were a total of approximately 300 booths run by governments, international organizations, ICT companies, and NGOs.

NICT and 13 major Japanese companies set up a Japan Pavilion for exhibits on the technologies, services, and applications that may help bring about the anticipated ubiquitous network society.

NICT set up exhibits on five subjects in cooperation with its Wireless Communications Department (YRC) and Information and Network Systems Department, as follows: (1) Overview of NICT; (2) S-band mobile terminals for satellite-based communications; (3) Helicopter-satellite communications system; (4) Applications of ubiquitous communications technology to disaster prevention (RF-ID, etc.); and (5) VHF-band multihop mobile communications terminals (a motorbike-mounted communications system). The ITU Secretary-General Utsumi, Japanese Internal Affairs and Communications Minister Takenaka, and leaders from many countries visited NICT's booth. In particular, we were able to offer a hands-on exhibit of the motorbike-mounted system with on-site support by NICT researchers. On the airplane back to Japan, we were handed a local newspaper (in Arabic) that devoted a great deal of space to reporting on this event, with numerous photos.

We would like to express our deepest gratitude to the many people that participated, and provided their assistance, in this event.

WSIS Tunis plenary session:
UN Secretary-General Annan, ITU Secretary-General Utsumi, and others

WSIS Tunis plenary session:
Statement by Internal Affairs and Communications Minister Takenaka

WSIS Tunis exhibition hall:
Numerous visitors to the NICT booth

Visit by Internal Affairs and Communications Minister Takenaka (in front of motorbike-mounted communications system)

Female Researchers at NICT vol.5

There are currently about 80 women researchers or staff members at NICT.
NICT News is pleased to feature a series of interviews with our female researchers.

Living Comfortably in a Complex Electromagnetic Environment

Dr. Kaoru Gotoh, Researcher, Communication System EMC Group, Yokosuka Radio Communications Research Center, Wireless Communications Department

Dr. Kaoru Gotoh
She received the B.E., M.E., and D.E. degrees all from University of Electro-Communications, Tokyo, Japan in 1996, 1998, and 2002, respectively. After a research associate of St. Petersburg University in Russia (2001) and Univ. of electro-communication (2002), she joined CRL (currently NICT) in 2003 where she has been engaged in the research on EMC for radio communication systems. She is proud of her vital forces so strong that she survived a terrible robbery during her stay in Russia.

My grandfather sparked my curiosity about information communications and radio waves.

—What kind of research are you doing now? And could you explain briefly how you first became interested in information communications and radio waves?

Gotoh: I'm a member of the Communication System EMC Group at Yokosuka Radio Communications Research Center, and we are engaged in research on EMC (electromagnetic compatibility) especially concerning wireless communication systems.
You know, the electromagnetic waves emitted from electric and electronic devices such as microwave ovens interfere with other devices or broadcast and communication services in the surrounding area. Also, introducing a number of new communication services in present day provide that the electromagnetic environment surrounding us gets increasingly more intricate. In these circumstances, securing the people's safety and reassurances regarding the use of wireless communication and broadcast services is very important, and we investigate the electromagnetic disturbance interference schemes with new and existing communication services accordingly. It is thus urgent that we conduct studies on electromagnetic disturbance measurement method, on development of disturbance measuring equipment, and on legal limits of disturbance emitted from the devices for prevention of electromagnetic interference. We have reported our achievements not only to an academic conference but to the International Special Committee on Radio Interference (CISPR), which is an international organization for the control of unnecessary radio waves emitted from electronic instruments, to contribute to the international standard for the restriction of electromagnetic disturbance.

I think that my grand father who was electrician sparked my interest in communication technology. When I was a girl, I adored repairing an old radio he gave me, motorbikes and fighter planes, and books including fine electric circuit diagrams and lots of mathematical formulas, just like as I loved playing the piano, doing embroidery. My direction was decided early on, I think, as I went on to a technical college just after finishing junior high school.

Exploiting the advantages of a "science town"

—Your workplace is located in Yokosuka Research Park (YRP), which is a science town specializing in wireless communications technologies. How is this research environment?

Gotoh: In Yokosuka Radio Communications Research Center, research and development of various wireless communications systems are underway through collaboration between industry, academia and government. So, it's a great advantage for us to be able to take in the newest trends in technologies. I'd also like to note a case that our group took charge of the development of a signal measuring method for a new wireless system, and was able to incorporate our EMC technology into the method. I was given the opportunity to see this collaborative research project just after joining CRL as a fixed-term researcher about three years ago, this experience gave me valuable insight into collaborative project.

Our group belongs to the EMC Center, whose main office is located in Koganei City. We work closely with members of the main office to carry out studies of measuring techniques and international standardization related to EMC. We are conducting our researches, sharing research policies and ideas by closely exchanging information, and visiting each other when necessary for experiments and so on.

For better life, positioning EMC as the central subject of R&D

—What is your dream or goal you hope to achieve through your research activities?

Gotoh: Currently, the mainstream of EMC research is to develop countermeasures against unnecessary electromagnetic waves. However, I hope to develop a system that is able to control electromagnetic environments proactively. The infrastructure for this is now being developed in preparation for the coming ubiquitous era. My idea is to build a network through which not only wireless instruments but also home appliances and other electronics can exchange the surrounding electromagnetic environment data, by attaching sensors and communications tags to those instruments. It will be very interesting if it becomes possible to create the optimum electromagnetic environment by adaptive-controlling on the whole the operation of electronic instruments and their internal EMC measures, in addition to communication methods, frequency bands, signal levels, and radiation directivity used by the communication system. Such a system can be realized only through collaborative research with researchers in various fields over industry, academia, and government. I believe that EMC can be the central technology of large-scale research projects because it is closely linked to relatively many other technical fields.

—EMC research seems to be industrially applicable to various fields, doesn't it?

Gotoh: Well, I understand that the need for EMC research originated in industry. So, I feel that it's a paradoxical question, but will answer according to the story (laughs). I have been studying a measuring method of electromagnetic disturbance referred to as APD measurement. Its effectiveness has been recognized internationally through theoretical verification based on large amounts of experimental data, and it is to be adopted as an international standard for the measurement of radio interference. This study is moving on to the next phase, that is, how to expand its applicability. No matter how effective the measuring method may be, it will be fruitless unless it is used widely. So it is particularly important to work with industry hereafter. The APD measurement allows you to estimate the degradation of communication quality of the system interfered by electromagnetic waves emitted from the measuring object. In other words, by establishing a product test procedure using the APD measurement, manufacturers will be able to ensure the reliability of their own products. This is just an example, and I'd like to work in active cooperation with industry to develop dedicated measuring equipment for such specific purposes.

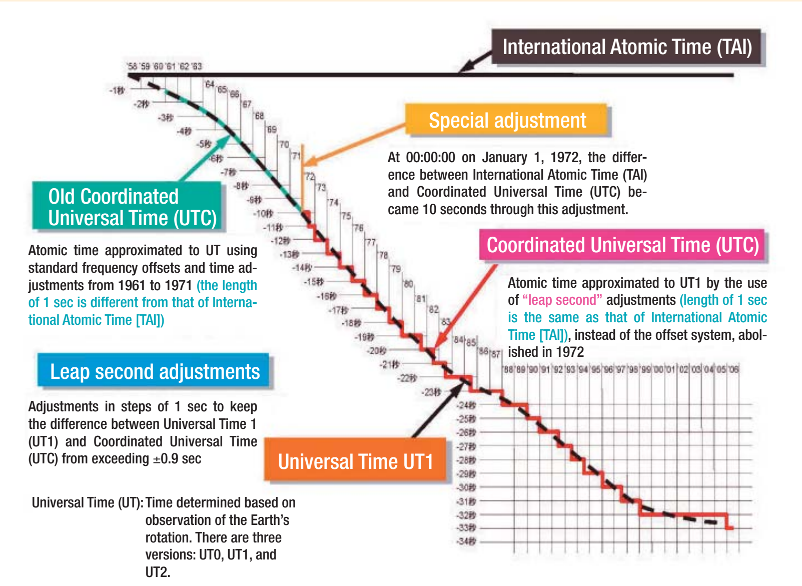
The APD measurement is not my original subject, but research into it had been conducted at the CRL since before. I'd like to familiarize application systems of the APD measurement, and to pursue my researches on new measuring methods that should be adopted as future international standards. I will continue to study, keeping in mind what is required of a new measuring method, and how its application will help the development of industry.

Dr. Gotoh working with APD measuring equipment

Information on the Leap Second

A leap second will be inserted just before 9:00 a.m. Japan Standard Time (JST) on January 1, 2006. Therefore, January 1 will be one second longer. This is the first leap second adjustment in seven years (the last one was on January 1, 1999). Until about 50 years ago, astronomical time based on the Earth's rotation had been used as standard time. With advances in science and technology, however, more accurate time measurement became essential. Today, extremely accurate atomic clocks are used to determine standard time. However, irregularities in the Earth's speed of rotation led to discrepancies between atomic and astronomic times. To keep this difference within ±0.9 seconds, atomic clocks are adjusted in steps of one second. This atomic time is called Coordinated Universal Time (UTC), and this one second to be inserted or remove in this adjustment is referred to as a "leap second." The difference between UTC and International Atomic Time (TAI; maintained without leap second since 1958) is now 32 seconds. This means that the Earth's rotation has slowed down by 32 seconds since the leap second system began in 1958. The rotation speed changes because of factors such as tidal friction, the global environment, and conditions of the Earth's interior. Leap second adjustments are performed at the same time throughout almost all of the world when necessary based on accurate observation and monitoring of the Earth's rotation. On this occasion, one second will be inserted after 8:59:59 a.m. JST on January 1, 2006 to indicate 8:59:60, followed by 9:00:00. These extra 60 seconds are counted only when a leap second is inserted. A number of services add this leap second in the provision of correct time: standard frequency and time signal emission (JJY), which serves as the standard for radio-controlled clocks; the dial-up standard time service "Telephone JJY" used by broadcasting stations; and the Internet time dissemination service "NTP." Note that many radio-controlled clocks will be one second fast until the next automatic reception of JJY. In this case, you will be able to correct your clock by performing manual reception after 9:00 a.m. To prevent any confusion or problems in societal activities and people's daily lives, we are providing information in advance and answering inquiries.

If you have any questions, please contact NICT's Japan Standard Time Group. The group's website is at http://jjy.nict.go.jp/.



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