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Activities of New-Generation Mobile Unit

— Realization of Reliable Ubiquitous Networks —

Hiroyo Ogawa, Executive Director, New-Generation Mobile Unit

Introduction

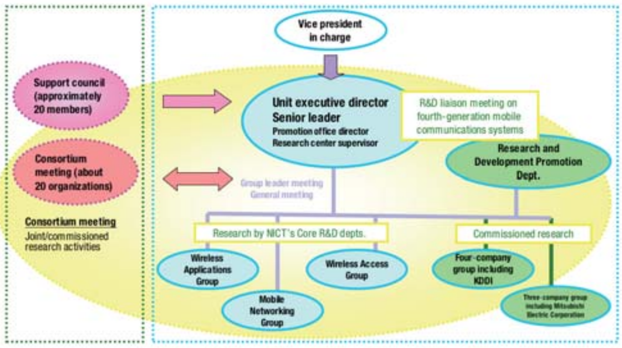
With the rapid spread of second- and third-generation mobile phones and wireless LANs, interest is growing worldwide in the possibilities of mobile networks beyond the third generation. NICT's predecessors, the CRL and TAO, previously conducted a new-generation mobile R&D project and commissioned R&D for fourth-generation mobile communications systems, respectively. After NICT was formed, we established a "unit" to coordinate these two activities. The New-Generation Mobile Unit works on the design, trial manufacture, and demonstration of new-generation mobile networks based on innovative concepts. Our partners are not limited to particular companies or organizations; rather, our aim is to provide broad support for the "u-Japan Strategy" proposed by the Ministry of Internal Affairs and Communications and to accumulate Japan's international competitiveness in this field.

Organizational structure

This unit consists of three groups from the Wireless Communications Department (carried over from the former CRL), two groups from the Research and Development Promotion Department (from the former TAO), a senior leader, and the Project Office. To reinforce collaboration in projects among industry, academia, and government, we set up a consortium of some 20 organizations involved in joint and commissioned research activities. We also established a support council of approximately 20 members, and we meet once a year to solicit advice from outside experts. To reinforce collaboration between the two departments, we hold regular R&D liaison meetings on fourth-generation mobile communications systems.

New-generation mobile network

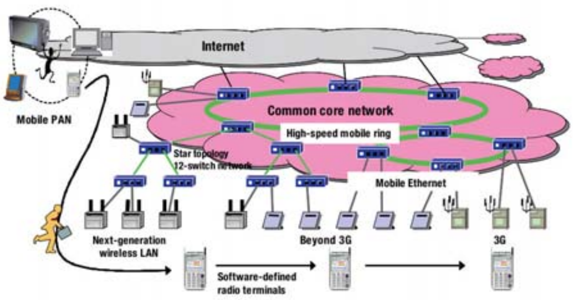
The coming generation of mobile networks after the third is referred to as the "fourth-generation" or "Beyond-3G." Various studies, mainly by telecommunication companies, are underway to realize mobile phone systems offering higher speed and larger



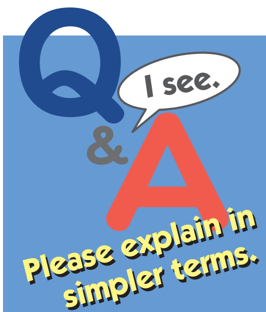
Structure of New-generation Mobile Unit

capacity. For the new-generation mobile networks, NICT is proposing wireless networks including not only mobile phones but also wireless LANs and other wireless access networks, which will enable the seamless handover among those different kind of networks, generations, or communication terminals. These new-generation mobile networks must also provide high security and avoid concentrations of traffic. We mean by this concept that through a paradigm shift from "quantity-oriented" to "quality-oriented" network technology, an IP-based network will eventually interconnect ubiquitous, various devices.

As a constituent technology in the realization of such networks, NICT's Yokosuka Radio Communications Research Center has pro-



Conceptual diagram of new-generation mobile network



Q What is a handover?

A Also known as a "handoff," this refers to a mobile terminal function of automatic switching between coverage areas or cells from one base station to another for continuous communication while the terminal is in motion. As an extension of this concept, the new-generation mobile network will enable the nearly seamless handover of terminals among different types of wireless networks, including functions such as the automatic detection of wireless networks, the position management, authentication, and billing of terminals. Expectations are thus high for the establishment of radically new mobile networks.

Q What is mobile Ethernet?

A This is a key component technology of the new-generation mobile network. More specifically, mobile Ethernet refers to an integrated network of various wireless systems such as third- and fourth-generation mobile terminals and wireless LANs. By controlling the secure handover of terminals such as mobile phones, mobile Ethernet will enable previously impossible communications among similar and dissimilar wireless networks.

posed, experimentally made, and evaluated a novel approach to enabling seamless handover among different types of networks and terminals, under a concept designated Multimedia Integrated Network by Radio Access Innovation (MIRAI). The method involves the separation of the traffic line (for sound, image, data, etc.) from the signaling line (dedicated to control signals), and uses the signaling line to exchange information called "contexts" on the communications environment, requests, and users' states and positions. The Yokosuka Center has also been conducting R&D of the following related key technologies:

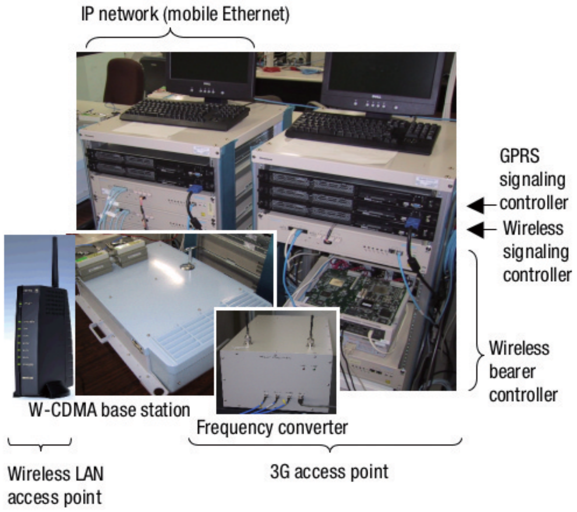
- Mobile Ethernet technology via open interface
- Secure platform technology resistant to wireless attacks
- Metropolitan-area high-speed mobile ring network technology to accommodate a large number of users and to disperse (or diversify or distribute) traffic concentrations
- Software-defined radio technology that can switch among different communications systems (wireless LAN, mobile telephony, digital broadcasting, etc.) via software alone
- High-speed/large-capacity mobile wireless access system technology capable of transmitting data at 100 Mbps to 1 Gbps

In parallel with these R&D, we have been making efforts to incorporate our research results into international standardization activities at the IEEE, ITU-R, and elsewhere.

Commissioned research projects

The Research and Development Promotion Department has two groups to conduct commissioned research. One group works on the R&D of an intelligent beam-forming (used to form multiple beams simultaneously), a spatiotemporally adaptive wireless resource allocation (used in combination with the beam-forming), and wideband mobile communications transmission, such as a wideband multicarrier transmission and a superconductor reception filter (device technology for the former). The other group engaging in the R&D of device and implementation technologies for software-defined radio—including a wideband antenna utilizing human bodies, a high-speed and low-power A/D conversion, and a sampling rate conversion filter.

Software-defined radio terminal prototype



Mobile Ethernet system for verification experiments on real-time handover between 3G mobile telephony and wireless LAN

Dedicated area for experiments on seamless handover

Plans for the future

We are now preparing for demonstration experiments of new/fourth-generation mobile networks by combining research results from the Wireless Communications with those of the Research and Development Promotion Departments. These experiments will be conducted using a testbed at the Yokosuka Research Park (YRP). This testbed features outdoor wireless LAN access points and experimental mobile base stations connected by a fiber-optic line installed along the roadside.

With a view to the establishment of future international standards, we are conducting these research activities with an emphasis on collaboration with universities and research institutes in Asia and in various Western countries.

We will continue to work toward the realization of reliable ubiquitous networks, one that goes beyond the conventional concepts of mobile communications to exploit the full potential of wireless technologies, regardless of where, by whom, with what tool, or in what environment they will be used.

Life & Tech-nology

● Efforts begin in earnest in the realization of a new-generation mobile network

Benefits of the new-generation mobile network include high-speed data communications comparable to FTTH (50 to 100 Mbps), high-quality motion pictures comparable to HDTV, and speedy and convenient web browsing on mobile phones, feeling no stresses of time required.

With the establishment of this new network technology, users will be able to receive services enabling to easily make proper use of networks and tools, without the need to recognize them, for example, with mobile phones or wireless LANs outdoors and with wired or wireless networks connecting various tools indoors .

Measurement of Subtropical Environment in Okinawa

— Observation of Typhoons Using Three Types of State-of-the-Art Radars —

Shinsuke Satoh

Director of Okinawa Subtropical Environment Remote-Sensing Center
Leader of Subtropical Environment Group, Applied Research and Standards Department

Ph.D. in meteorology. Joined the CRL in 1995. Engaged in R&D of precipitation radar on board Tropical Rainfall Measuring Mission (TRMM), dual-frequency precipitation radar on board the main satellite for Global Precipitation Measurement (GPM), and the C-band Okinawa Bistatic Polarimetric Radar (COBRA). Worked as Visiting Researcher at the University of Oklahoma from 1998 to 2000; Deputy Chief Engineer at JAXA from 2002 to 2004. In present position since 2005.

Introduction

Okinawa is located in the subtropical zone along the paths of the Kuroshio (the Japan Current) and the typhoons that bring enormous amounts of heat and water vapor from the tropics, being ideally placed for weather forecasting and the predictions of oceanic conditions, and the study of climate changes in Japan and the surrounding area. In addition, in order to investigate the changes of hydrologic circulation in the whole East Asia and the effects of global warming, Okinawa is recognized as an important site for observing the maritime subtropical environment. Accordingly, NICT's Okinawa Subtropical Environment Remote-Sensing Center (referred to simply as the "Okinawa Center" below) developed three types of radio wave remote sensing facilities: a "Long-Range Ocean Radar" for measuring ocean currents, the "400-MHz Wind Profiler" (WPR) for measuring high-altitude winds, and the "C-band Okinawa Bistatic Polarimetric Radar" (also known by the acronym COBRA) for measuring three-dimensional precipitation distribution. We set up the Long-Range Ocean Radar on Ishigaki and Yonaguni islands, the WPR in Ogimi Village, and installed COBRA on a mountaintop in Nago City. Operation of these facilities and related data collection can be performed remotely from the Okinawa Center in Onna Village (Figure 1). We incorporated a large number of new ideas and state-of-the-art technologies into these next-generation observation sensors, enabling us to observe phenomena hidden from traditional observation systems.

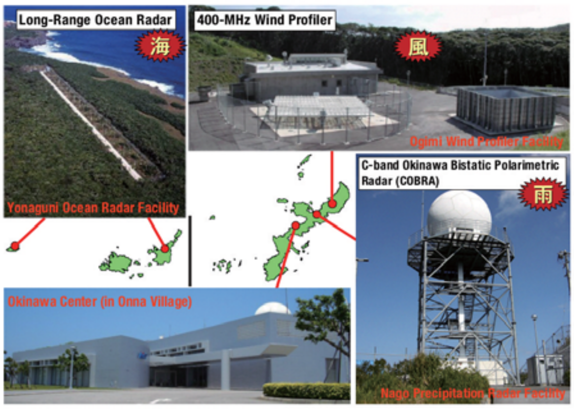
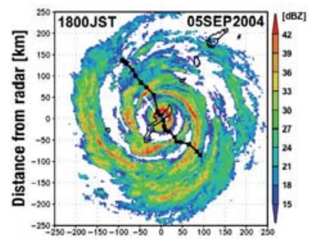


Figure 1: Three observation facilities developed by Okinawa Center

Observation of typhoons using three types of radars

In this article, I will present research results relating the observation of typhoons the three radars were designed to observe. Figure 2 shows a COBRA observation result of typhoon No. 18 (2004), which passed along Okinawa's main island. The radar reflectivity (rain rate) distribution observed by COBRA shows the entire typhoon image, which featured a diameter of 500 km. Although it looks similar to the familiar radar images offered by Japan Meteorological Agency, this observation result was obtained using a transmission power of only 10 kW, thanks to a pulse compression function, which is much lower than a conventional-radar transmission power of some 250 kW. In addition, through transmitting of linearly polarized waves of +45° and receiving of both horizontally and vertically polarized waves simultaneously, COBRA can obtain various polarization parameters to determine the type of precipitation particles (rain, snow, hail, etc.) and can make corrections for rain attenuation. Moreover, its dual pulse repetition frequency (PRF) function enables us to observe Doppler velocities of strong winds (as with a typhoon) in the observation range of over 250 km. As you can



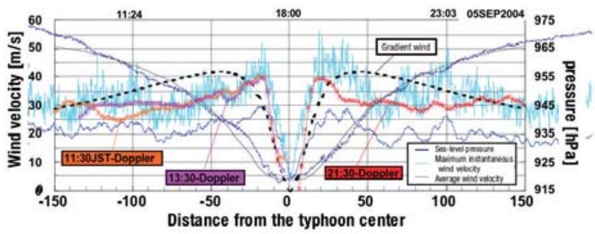
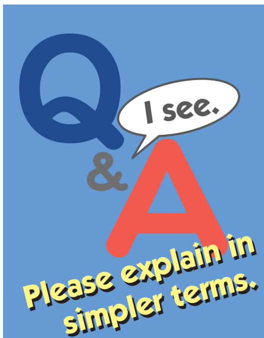


Figure 2: Reflectivity of Typhoon No. 18 (in 2004) and path of the typhoon center observed by COBRA (left); Temporal variations of atmospheric pressure and wind velocity, and averaged tangential wind velocities estimated from Doppler velocities (bottom)



Q What is a pulse compression function?

A To measure the distance to an object, a normal weather radar transmits pulsed radio waves for an extremely short time and then executes a receiving operation that takes approximately a thousand times longer than the transmitting pulse. To measure light rain, the transmitting pulse must be lengthened with the expense of range resolution. Using the pulse compression function, COBRA transmits frequency-modulated pulse that is a hundred times longer than normal and demodulates it at the time of reception. In this way, COBRA enables highly sensitive observation with a range resolution of 75 to 300 m. Moreover, with the dual cycle mode (using alternating long and short pulses), we solved the issue of invisible range in the vicinity of the radar, establishing that COBRA can perform as well as or better than existing weather radars.

Q What is the Global Precipitation Measurement (GPM) project?

A GPM is an extended follow-on project to the ongoing Tropical Rainfall Measuring Mission (TRMM), and is one of the international earth observation satellite projects carried out mainly by NASA, JAXA, and NICT. Consisting of one core satellite equipped with a dual-frequency precipitation radar (in a sun-asynchronous orbit) and several constellation satellites equipped with microwave radiometers (in sun-synchronous orbits), GPM is designed to perform highly accurate global precipitation measurement every three hours. This project is expected to meet various societal demands for improved accuracy in weather forecasts, flood predictions, water resource management, and studies of changes in precipitation distribution due to global warming.

see, the averaged tangential wind velocities estimated from the Doppler velocities are in good agreement with the temporal variation of wind velocities observed on the ground, and the gradient wind (theoretical typhoon wind velocities derived from the atmospheric pressure variation) as shown in Figure 2 (bottom). Figure 3 shows wind directions and speeds of the same typhoon at altitudes up to above 16 km, observed by the 400-MHz WPR. As is clear from the figure, the wind directions change clockwise over time, and the winds become stronger at lower altitudes as the typhoon approaches. Figure 4 shows the distribution of ocean surface currents observed by the Long-Range Ocean Radar when the center of Typhoon No. 16 (2001) was located at 160 km northwest of Ishigaki Island. In the figure, areas with high current flow represent the Kuroshio Current, and here we see that the typhoon's strong winds have caused a counterclockwise surface current. Recently we are making an attempt to improve the accuracy of typhoon forecasts, etc. using this sort of observation data as a joint research with the Meteorological Research Institute.

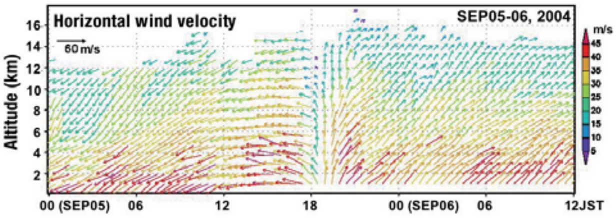


Figure 3: Height/time cross-section of horizontal wind velocity observed by 400-MHz WRP

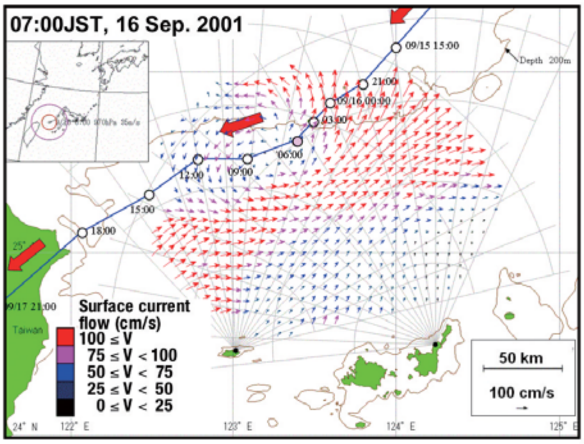


Figure 4: Surface current field observed by Long-Range Ocean Radar during passage of Typhoon No. 16 (2001)

Measurement of new physical quantities

In the above section, I described the basic physical quantities observable using the individual radars in the form of some results of typhoon observations. Here, as an example of measurement of new physical quantities, I will now present a research into the calculation of mid-air raindrop size distribution (relation between the size and number density of raindrops), for which no effective observation measures have ever been developed, from WPR observation data. When observed by the 400-MHz WPR (the existing only one in Japan), the atmospheric echo (Bragg scattering) and precipitation echo (Rayleigh scattering) have the same level of reflectivity. If these echoes can be separated, it will become possible to obtain the raindrop size distribution at specific altitudes. In the case of the observation example shown in Figure 5 (top-left), the atmospheric and precipitation echoes can be clearly discriminated; as a result, we can obtain the raindrop size distribution from the precipitation echo's Doppler spectrum (i.e., the spread of Doppler velocities) corresponding to raindrop sizes (Figure 5, bottom). It is also possible to improve the estimation accuracy of raindrop size distribution by calibrating the WPR reflectivity, which is unnecessary for wind measurement, using the data of simultaneous observation with COBRA (Figure 5, top-right). In addition, the ocean radar is expected to be applied to the detection of tsunamis, and COBRA is used also to perform the observation of clear air boundary-layer echoes, which relate to the generation of clouds and rain, though unfortunately it's impossible to discuss them further due to limitations of space.

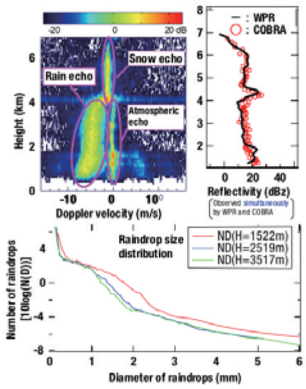


Figure 5: Doppler spectrum observed by 400-MHz WPR (top-left), vertical distribution of reflectivity (top-right), and calculated raindrop size distribution (bottom)

Future Roles of the Okinawa Center

Although remote-sensing technologies can be used to measure a number of physical quantities, many factors may lead to errors in observation results. For validation and calibration purposes, those have conventionally been compared with the results of direct measurement. However, it is sometimes difficult to make a comparison between them due to temporal/spatial inconsistencies or changes in environmental conditions. Some physical quantities cannot be measured directly by any other method. In this context, the method of physical calibration has recently been proposed to determine a comprehensive set of physical elements, including unmeasurable physical quantities, using available observation methods and numerical models, with the final aim of reconstructing a complete atmospheric and oceanic conditions. Those results are expected to be useful not only in the calibration of remote-sensors, but also in the verification of global warming prediction models, and the development of algorithms for onboard satellite sensors, etc. Okinawa has been selected as a candidate for the integrated ground validation site (a so-called "super site") in the international GPM project. Observation data obtained at Okinawa Center is already used in the development of such algorithms. We also offer the observation data to the Japan Meteorological Agency and the Japan Coast Guard, and we are conducting joint researches on 12 subjects with universities and research institutes. In addition to the operation and observation experiments of the three radars, we are planning to tackle new challenges, with the cooperation of those partners: the development of algorithms to calculate new physical quantities, the technical improvement of the remote-sensors and the addition of new functions to them, and the realization of new validation and calibration methods to ensure the reliability of observation data.

Life & Tech-nology

● Development of ocean radar through accumulated expertise

Okinawa Center began R&D in ocean radars in 1986. Since, there used to be remarkable incidents that our radar technology attracted a great deal of attention. In January 1997, the Russian tanker Nakhodka was damaged and sank in the Japan Sea, causing heavy oil spills. We offered our ocean-current observation data in the surrounding waters to make predictions about the flow of spilled oil. To obtain this data, we observed the distribution of the ocean current within approximately 50 km far from the coast every two hours using our HF ocean radars placed in Wajima and Suzu Cities, Ishikawa Prefecture. In 1999, we conducted special observations using the HF ocean radars, and discovered that coral spawn near the Kerama Islands (located to the west of Okinawa's main island) drifted to areas around the main island, helping in the recovery of coral reefs there. Based on this HF ocean radar technology, we have developed our Long-Range Ocean Radar enabling us to observe the flow of the Kuroshio Current every 30 minutes with an observation range of 200 km.

Shunkichi Isobe
Research Center Supervisor, Yokosuka Radio Communications Research Center, Wireless Communications Department

2nd Next Generation Wireless Technology Showcase

— Yokosuka Center Exhibited Its R&D Results —

From Wednesday, July 13 through Friday, July 15 2005, "Wireless Japan 2005," the "2nd Next Generation Wireless Technology Showcase," the "ITS Expo Tokyo" and the "Network Robot Expo" took place concurrently at the Tokyo Big Sight. Every year, companies offering the latest solutions or technologies gather at this set of Japan's largest trade shows specializing in wireless and mobile technologies. This was the 10th such event, with thirty-four thousand visitors over the three days.

NICT booth

Yokosuka Radio Communications Research Center participated with an exhibition at the 2nd Next-Generation Wireless Technology Showcase. We ran a booth measuring six by four meters next to booths set up by the YRP R&D Promotion Committee and various university laboratories and venture companies located in YRP. We set up a small booth for each of the following themes for exhibits and demonstrations:

- Mobile Ethernet Technology
- Next generation mobile network
- Software-defined radio technology for new generation mobile communications systems
- Wireless repeater and network technologies using millimeter-wave
- New generation high-altitude airborne wireless — the Stratospheric Platform Project: Achievements and Vision for the Future
- UWB sensor network
- Inter-vehicle communications technology for safety operation support
- Collaborative research in Asia (NICT Asia Research Center)

Demonstrations at these booths attracted consistently large crowds. Several of them in particular drew a great deal of attention: a communications control technology enabling high-speed handover between different types of wireless networks, a bookmark handover system that enables mobile users to peruse shop/product information obtained automatically from television or magazines, and software-defined radio, which enables seamless common-platform communications between 3G mobile communications systems and high-speed wireless LAN systems.

The "Asia Wireless Summit" was held on the second day as a special program to commemorate this 10th anniversary. There were speeches and panel discussion sessions attended by officials in charge of communications policies in various Asian countries, as well as the representatives of Japanese mobile phone carriers and communications equipment manufacturers. NICT Vice President Omori delivered a speech entitled "Research and Development Required to Grow the Asian ICT Market," and discussed R&D collaboration between NICT and its partners in other Asian countries.

Exhibits at Network Robot Expo

After the summit, Minister Aso for Internal Affairs and Communications visited NICT's booths and observed hands-on exhibits of software-defined radio, mobile Ethernet, millimeter-wave relay network technologies, and an overview of the NICT Asia Research Center.

At the Network Robot Expo held in the same venue, NICT's Keihanna Human Info-Communication Research Center ran a booth on the theme of "Interactive Interface Robots" with exhibits showing the roles of robots in ubiquitous homes.

Then Home Affairs Minister Aso listens to an explanation of millimeter-wave technology

Female Researchers at NICT vol.2

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.

Insulating Materials and EMC Support Information Communications Industry

Kaori Fukunaga, Senior Researcher, EMC Project Office, Wireless Communications Department

Dr. Kaori Fukunaga
Received Ph.D. in engineering at Tokyo Denki University in 1993 while working at Fujikura Electric Wire Corporation (currently Fujikura Ltd.). Joined CRL (currently NICT) in 1994. Engaged in research into dielectric insulating materials and educational campaigns on the subject of EMC. Hobbies include watercolor painting and an appreciation of art and architecture. Special skills: Italian language

The difference between NICT and corporate laboratories

—Could you tell us how you became interested in your current field of research? Based on your experience working in a laboratory in a private company, do you note any significant differences from the environment at NICT?

Fukunaga: The most exciting field for me was always art—painting and architecture—but I chose to study electricity, which seemed more familiar and straightforward. Since research into insulating materials involves a wide range of fields, such as physics, chemistry, and electricity, my current profession keeps me engaged. When I was working as part-time instructor at a university after leaving the corporate laboratory, I came across a recruiting ad by the CRL (currently NICT) in the Journal of the Japan Society of Applied Physics. I applied for the position and was hired, nearly 11 years ago.

Between research institutes like NICT and company laboratories, you see a major difference, for one thing, in the way people think about budgets. At NICT, individual research projects are allocated their respective budgets. On the other hand, private companies are looking to make profits through the commercialization of research results. So it's inevitable that research projects are carried out based on product life cycles. In manufacturing, research efforts are rewarded with the commercialization of their results. However, it's difficult to carry out necessary basic researches. For example, when conducting a service-life test on three materials, corporate researchers are only required to determine which material has the longest life; they must then move on to the next step, without asking "why is this the case?" They have to deliver products on time. In this respect, I appreciate how naturally we are allowed here at NICT to delve into themes important, but untouchable in the development field, such as the reasons behind and the evaluation of the test method itself.

Printed-circuit boards support Japanese industry

—Could you explain your current research activities and anticipated future developments in these areas?

Fukunaga: I am working to promote research into the reliability of printed-circuit boards (PCBs) used in information-communication equipment, adopted in an in-house funding system, as well as educational campaigns relating to EMC (electromagnetic compatibility). Although the reliability of PCBs is an important issue for Japanese industry as a whole, different products demand different degrees of reliability. For example, PCBs for in-vehicle inverters demand extra-high reliability, while the product lives of mobile terminals are in fact shorter than the lifetimes of their component materials. I'd like to come up with suitable testing methods for individual products, studying not only the service lives of various materials but also the way they deteriorate. Recently, there is growing concern about the high-frequency characteristics of insulating materials for PCBs. The characteristics of materials simply for supporting mounted high-frequency components hasn't been measured earnestly, though such measurement could be effective for EMC design. So this year, I began to study methods of evaluating the high-frequency characteristics of general-purpose dielectric materials.

In international conferences, participation is essential

—You have attended a great number of international conferences. Do you have any comments, in particular from your point of view as a women researcher?

Fukunaga: At international conferences, we female researchers may have an advantage of having our faces and names known more easily than males. Of course it's essential that the contents of presentations be sufficiently informative and topical, but in addition, I think because there are relatively fewer female participants, we often better impress others there.

I believe that as for international conferences, it's very important to participate in them serially, regardless of sex. Because, I know, we researchers can get some information from one another only after we become close friends. For example, I am now working with a French space research institution. That is also a project that began thanks to a connections with a friend of another friend.

—You place a lot of importance on fostering younger researchers, don't you?

Fukunaga: Researches into insulating materials and EMC is a field that does not receive a great deal of attention, but once there is some problem or failure, we have to accept responsibility. In fact, it plays an important role in supporting the spectacular industry of ICT and prosperous modern life. For this reason, I'd like to meet a lot of young researchers wherever I visit, companies or universities, and contribute to increasing people as further as possible that will lead future research in this field.

—You say you are a coordinator-like engineer.

Fukunaga: The technologies themselves are developed by our brilliant researchers. My main task is coordination, or applying these technologies to industry, the field of product development, where they will be utilized. Unlike pure science, engineering must be useful in some way, I believe. I'd like to continue engaging in technology developments supporting information and communications through works in boundaries, such as those between basic research and product development, among industry, academia and government, between Japan and Europe.

A party at an international conference in Kitakyushu in June 2005. Dr. Fukunaga always wears a kimono at international conferences held in Japan.

Greetings from the Newly Appointed Vice President

— Vice President of NICT —

Appointed on August 15, 2005

Masataka Kawauchi

[Strategic Planning]

The evolution of life on Earth is said to be the result of changes adopted by living organisms to survive cataclysmic changes in the global environment. NICT has recently been facing major changes in its own environment, such as the shift in the government's policy goals from the "e-Japan" to the "u-Japan" strategy, the merger of the CRL and TAO, and the debate on organizational reviews as we approach NICT's second term. I believe that NICT is being tested on its ability to change and adapt to these situations. As a research institute, NICT continues making utmost efforts to be a powerful institution capable of contributing the society, mass-producing high-level activity results.

Science Camp 2005 — Kashima Space Research Center —

From August 8 through 10, the Kashima Space Research Center served as one of the sites for the Science Camp 2005, hosted by the Japan Science Foundation. Our program this year was entitled "Three Experiments to Help Understanding Information and Communications, and Space Science," and received 12 high school students from Yamagata, Okinawa, and other parts of the country. Since this topic—information and communications, and space science—was very popular among the applicants for this event, the participants were selected from those who had specified it as their first choice. These participants stayed three days and two nights, conducting three experiments: "Observation of solar radio waves using the world's smallest self-made radio telescope" (Photo 1, Instructor: Dr. Ryuichi Ichikawa, Senior Researcher, Radio Astronomy Applications Group); "Control experiment using cluster satellite robots" (Photo 2, Instructor: Dr. Hiroaki Umehara, Senior Researcher, Space Cybernetics Group); and "Experience of error correction in digital communications" (Photo 3, Instructor: Dr. Tadashi Minowa, Researcher, Mobile Satellite Communications Group). Although it was hard work for the instructors to prepare for these experiments, they were impressed by the students' curiosity about science and technology, their speed with which they learned, and their overall creativity. A review meeting was held on the final day for the participants to present their results. During a Q&A session, the instructors and students had an enthusiastic discussion about improvements on the experiments, among other topics; the meeting in fact lasted far beyond the scheduled time.

Photo 1

Photo 2

Photo 3

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