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R&D into Software-Defined Radio for Next-Generation Mobile Communications Systems

— Support for All Types of Wireless Communications Systems via Single Radio Device —

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Received Ph.D. in engineering at Graduate School of Engineering, Osaka University in 1995. Joined CRL of the Ministry of Posts and Telecommunications (currently NICT) in 1995. Worked as Postdoctoral Fellow at Technical University Delft in Netherlands. Now engaged in research on mobile radio communications systems using digital signal processing.

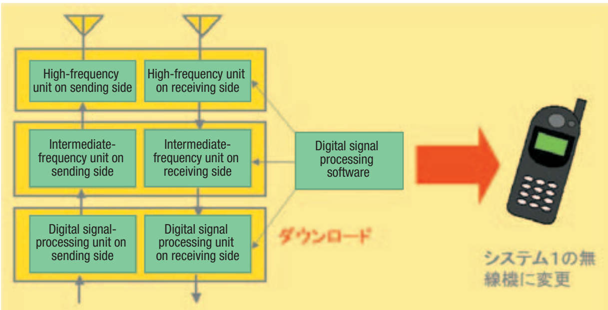


Figure 1: Overview of Software-Defined Radio

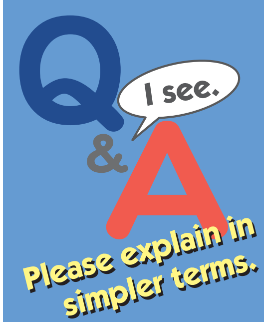
Photo 1: Appearance of Newly Developed Software-Defined Radio Unit
Left: Display (with video camera)
Right: Radio signal processor

In the field of mobile communications, a series of new systems have recently been appearing to support increasingly high-speed and multifunctional wireless communications. We now expect to see the advent of a next-generation mobile communications system that can automatically select, based on the user's location and request, the optimum line for conveying information rapidly to the intended destination. However, an impractical number of different radio units would be required to be able to select from among all of these wireless systems. Software-Defined Radio (SDR) offers a solution to this problem. Conventionally, wireless terminal functions are processed using analog circuitry. In contrast, SDR uses digital circuitry, in which wireless terminal functions are processed by software. The user can thus use a desired wireless communications system simply by switching between software programs (Figure 1).

NICT started R&D into SDR units in 1997, and in 1999 and 2001 succeeded in developing SDR units for use in intelligent transport communications. However, these SDR units did not yet embody next-generation mobile communications encompassing not only intelligent transport communications but also other wireless communications systems, such as mobile phones and wireless LANs. This was due to the lack of a common signal-processing platform and communications systems switching software.

For SDR unit signal processing, we have now developed a Common Development Platform for Software-Defined Radio consisting of general-purpose devices and radio-frequency components. We then used this common platform to make an actual SDR unit.

As shown in Photo 1, the newly developed SDR unit consists of a display (equipped with a video camera) and a radio signal processor. As shown in Photo 2, the radio signal processor includes an FPGA board comprised of NICT's proprietary rewritable FPGA devices, a CPU board made up of CPU devices, and radio-frequency boards featuring an open interface; together these devices form a common platform. The platform adopts ITRON, increasingly used in mobile phones, for the CPU board's operating system (OS). Software developed on this platform can thus be easily ported to mobile phone systems. The FPGA board handles the physical layer—dedicated mainly



Q What is the "FPGA" used in devices and boards?

A FPGA stands for Field Programmable Gate Array, a programmable LSI.

Q What is ITRON?

A TRON stands for The Real-time Operating System Nucleus, a type of real-time operating system installed in industrial equipment and home appliances. Related standardization projects are open to the public. ITRON refers to Industrial TRON, an OS for embedded systems used in industrial equipment.

Q What are physical, data link, and network layers?

A The physical layer specifies the physical means of connection and transmission in a wireless network. The data link layer specifies the rules of wireless communications, such as those governing retransmission requests. The network layer specifies methods of network communications at and below the data link layer.

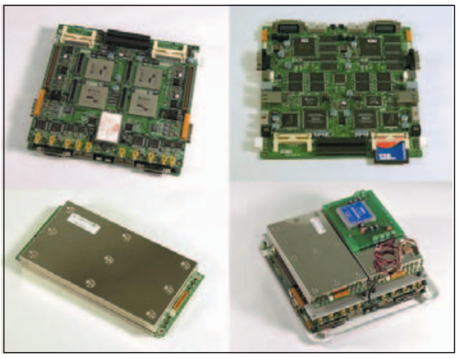


Photo 2: Common Development Platform for Software-Defined Radio
Upper left: FPGA signal processor Upper right: CPU signal processor
Lower left: Radio-frequency signal processor Lower right: Combination of all processors

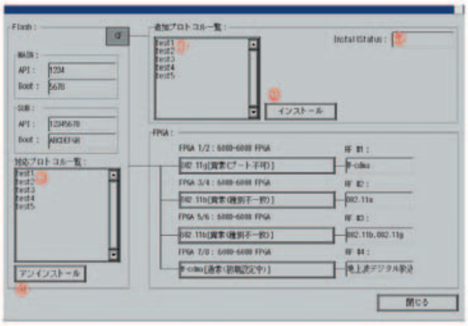


Figure 2: Software Installer
(1) List of communications software items in CompactFlash (2) Install button
(3) List of communications software items in radio unit's memory
(4) Uninstall software (5) Installation status indicator

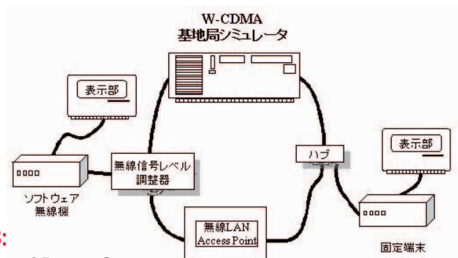


Figure 3:
Overview of Demo System

項目	仕様
FPGA board	
ADC	2ch/170 Msps/12bit/0dBm input
DAC	2ch/500 Msps/12bit/0dBm output
FPGA	Xilinx XC2V4000.6000.8000 (selectable)
IF to RF board	Analog in (2ch)/Analog out(3ch)/Cont(5bit)
External clk I/F	Input 5M-66MHz, 0dBm 2.4.8.16 times clk generate automatically
External output	CPU-IF (Max 80Mbyte/s) External output(Max 600Mbyte/s)
CPU board	
CPU	430 MIPS(240MHz)×2
OS	μ-ITRON (PrKERNEL v4)
I/O	Compact Flash, RS232C,USB,Ethernet/JTAG
RF boards	5GHz帯用ボード＋2GHz帯用ボード

Table 1:
Basic Specifications of Common Platform

to wireless transmission—and the CPU board handles the data link and network layers, which deal mainly with protocols. The radio-frequency signal processor supports 2-GHz and 5-GHz frequency bands. Table 1 summarizes specifications of these boards.

We have also developed software for the installation of various software items on this platform and system-switching software that allows you to switch among communications systems as desired (Figure 2). A CompactFlash card stores software items for implementing communications systems. By loading this card in the back of the SDR unit and running the installation software, you can easily install any of these systems. You can specify the priorities of these system software items and the conditions for system switching. You can also select between automatic and manual switching. Further, we prepared software to implement 3G mobile communications (W-CDMA) and high-speed wireless LAN (IEEE802.11a) systems through the use of this common platform.

We have already succeeded in incorporating the physical, data link, and network layers into these software programs; you can make changes as appropriate on the common platform. The W-CDMA software can connect to commercially available W-CDMA base station simulators. By combining a radio signal processor and display, you can transmit moving pictures through W-CDMA and IEEE802.11a, and perform voice communications using VoIP (Voice over IP, a voice communications protocol used on IP networks). Figure 3 shows a system configuration showing an example combination of these components. An SDR unit connects to a fixed network terminal via both W-CDMA and a wireless LAN access point. First, the level of the radio signal of the wireless LAN access point lowers and the level of the signal of W-CDMA rises, W-CDMA software will be downloaded to the SDR unit—video transmission and voice communications will then be carried out through the W-CDMA network. Next, when the level of the radio signal of the wireless LAN access point rises and the level of the W-CDMA signal lowers, the connection will automatically switch to the wireless LAN; video transmission and voice communications will then begin seamlessly through a high-speed wireless line of tens of megabits per second.

The successful development of this SDR unit is a first step toward commercialization of a next-generation mobile communications system based on SDR. In addition to W-CDMA and IEEE802.11a, we are planning to incorporate various mobile communications systems and broadcast-receiving circuits into software. We will next proceed to development of an SDR unit that can allow you to switch smoothly among as many types of communications and broadcast systems as you wish. We are also investigating transfer technologies applicable to common-platform and related software.

Life & Tech-nology

● Numerous wireless communications services available through a single terminal

It will probably become possible in the near future to select any of the desired communications systems as appropriate just by purchasing a single terminal that includes this software technology. This "Software-Defined Radio" unit is in fact an ideal radio, allowing you to receive PHS, ETC, GPS, radio broadcasting, and other services closely related to our daily life, without the need to carry several communications devices.

R&D into Techniques for 3D Visualization of Radio-Wave Leakage from Electronic Devices

Hiroyasu Ota

Sendai EMC Research Center
Collabaorative Research Management Department

Joined Sony Corporation in 1977 to engage in research and product development on ferrite parts and switching power supplies. Transferred temporarily to the Sendai EMC Research Center, TAO in 2001. Since then, engaged in R&D into techniques for 3D visualization of radio-wave leakage from electronic devices.

Kazumasa Taira

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Joined the Communications Research Laboratory in 1991 and engaged in research on propagation characteristics of radio waves in indoor wireless and land mobile communications. Transferred temporarily to the Sendai EMC Research Center, TAO, in 2001. Since then, engaged in R&D into techniques for 3D visualization of radio-wave leakage from electronic devices.

Introduction

With the recent rapid increase in small electronic devices using wireless communications technology, an increasing number of malfunctions have arisen inside devices due to interference, in addition to communication failures between devices. Any attempt to implement countermeasures entails the determination of the source of unnecessary radio-wave leakage. This is inherently difficult, as radio waves are naturally invisible.

To address this problem, we are conducting R&D into techniques for visualizing radio-wave leakage from electronic devices.

Overview of Radio-Wave Visualization Techniques

Based on the applicable observation point for visualization of wave leakage, R&D at Sendai EMC Research Center is divided into two subprojects: "Techniques for visualization of nearby radio waves" and "Techniques for 3D visualization of radio waves from a distance." The former project is aimed at developing a probe that can measure electric and magnetic fields (emitted as a by-product of radio waves) with minimum disturbance, followed by observation and visualization of radio-wave leakage from a nearby electronic device (Figure 1). The latter project is aimed at developing techniques for rapid measurement of an electric-field distribution at some distance from the electronic device, in addition to the development of algorithms for high-accuracy estimation of the source locations of wave leakage using the obtained measurement data (Figure 2). Moreover, using these techniques, we aim to create a system that can be used in the analysis of emitted electromagnetic noise and in the verification of the effectiveness of various countermeasures against noise.

Figure 1: Techniques for Visualization of Nearby Radio Waves

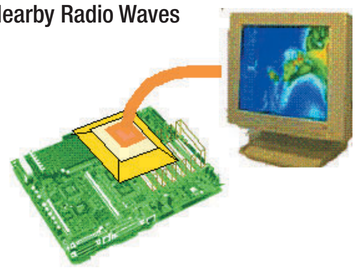
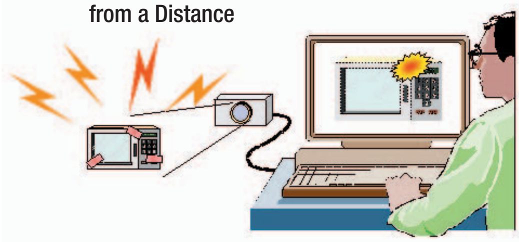


Figure 2: Techniques for 3D Visualization of Radio Waves from a Distance



Progress of R&D

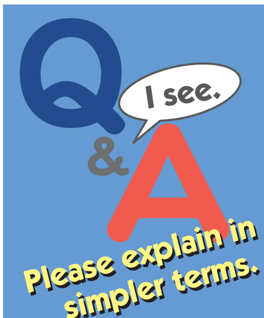
(1) Techniques for visualization of nearby radio waves

Minimally-invasive optical magnetic field probe

To measure an electric/magnetic field intensity distribution accurately in the proximity of an electronic circuit, it is necessary to use a probe offering minimal impact on circuit operation and electromagnetic field distribution, high spatial resolution, and an outstanding ability to separate electric and magnetic fields. In this project, we developed a double-loaded optical magnetic field probe using an electro-optical crystal whose refractive index changes according to electric field intensity, and verified that this probe could perform accurate measurement even at gigahertz frequencies (Photo 1).

Visualization of magnetic field distribution in the proximity of patch antenna

Figure 3 shows a magnetic field distribution in the proximity of a patch antenna that emits the 2.4-GHz radio waves used in wire-



Q What does the "EMC" mean in the name of this research center?

A EMC stands for electromagnetic compatibility. EMC refers to the absence of electromagnetic interference in a device's operation in the presence of wireless equipment in the living environment, or proper device operation in the event of a certain amount of interference.

Q What's an array antenna?

A An array antenna refers to a system of small antenna elements positioned in an array; the phases of signals flowing through these elements are controlled to reorient the beams electronically. The Sendai research center is conducting R&D into algorithms for quickly analyzing phase and amplitude information obtained from this antenna and for 3-dimensional visualization of electromagnetic field distribution in the space in which the relevant device is situated.

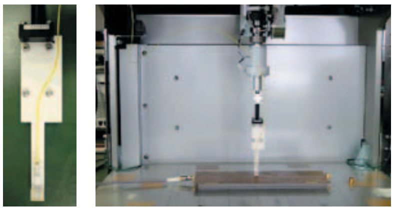
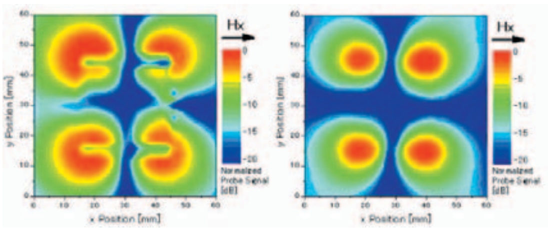


Photo 1: Measurement of a Magnetic Field Distribution on a Circuit Board Using an Optical Magnetic Field Probe

less LANs. We used two probes in the measurement: a conventional magnetic field probe and an optical magnetic field probe developed for this project. In the case of the conventional probe, which has a metal cable, the antenna's operation is affected and the magnetic field distribution is disturbed. On the other hand, in the case of the optical magnetic field probe, which sends signals though a fiber optic cable, the distribution is virtually undisturbed; measurement results are therefore accurate. To measure electromagnetic field distributions quickly at even higher frequencies in the proximity of electronic circuitry, we are planning to develop a system integrating multiple miniaturized probes.



(a) Measurement results using a conventional probe

(b) Measurement results using an optical magnetic field probe

Figure 3: Magnetic Field Distribution in the Proximity of Patch Antenna

(2) R&D into techniques for 3D visualization of radio waves from a distance

Estimation of wave source locations using arrival direction estimation techniques

In this project, we are conducting studies on the estimation of a wave source location by determining the direction of arrival of radio waves from a distance several wavelengths from the wave source. Since the wave-source location is estimated using phase distribution measured by an array antenna near the source, the accuracy of the arrival-direction estimation will decrease due to the insufficient distance. We have devised a method to reduce this effect, using computer simulations and experiments to verify its effectiveness in improving the accuracy of estimation.

Estimation of leakage-wave source locations on a microwave oven

Using the above-mentioned technique for estimating wave sources, we conducted studies to determine leakage-wave emission locations on a microwave oven. The amplitude and frequency of such leakage waves change over time. Using these cyclical signal changes, we devised a method of measuring the phase distribution of the array antenna elements. Photo 2 shows actual measurement of radio waves leaking from a microwave oven. Figure 4 shows the centers of the radio-wave emissions estimated from the measurement results. We measured leakage waves from the front of the microwave oven; with increasing proximity to the center of emission, the red color becomes deeper. Estimation (a) is based on horizontally polarized wave components (the electric field oscillates horizontally); (b) is based on vertically polarized wave components (the electric field oscillates vertically). These results show that there is a difference in the number and locations of leakage-wave sources between horizontally and vertically polarized wave components. In (b), a center of emission is located near the top of the microwave oven, which suggests that leakage waves are emitted from the entire body. We plan to conduct further studies to investigate this issue.

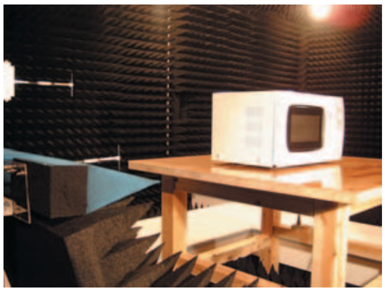
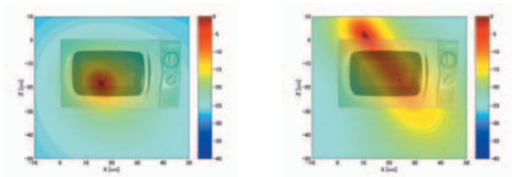


Photo 2: Measurement of the Spatial Phase Distribution of Radio Waves Leaking from a Microwave Oven

Figure 4: Centers of Wave Emissions Estimated from Measurement of Leakage Waves from Microwave Oven



(a) Horizontally polarized wave components in radio-wave leakage

(b) Vertically polarized wave components in radio-wave leakage

Conclusion

The radio-wave visualization techniques developed in this project are expected to be useful not only in designing higher-density circuits and in increasing the speed of wireless communications, but also in solving various problems related to studies in electromagnetic compatibility (EMC). In the final stage of this project, we hope to make a prototype of a radio-wave visualization system that organically combines the developed techniques, and to verify the usefulness of these visualization techniques.

Life & Technology

● 3D leakage-wave visualization techniques receive increasing attention with daily common use of radio waves

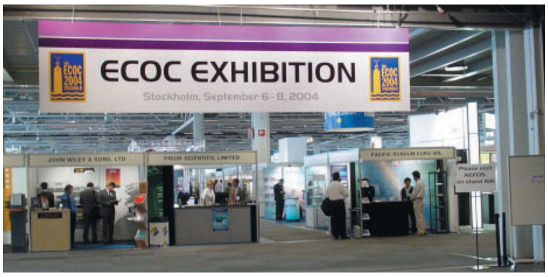
Many appliances we use in daily life employ radio waves, from mobile phones to microwave ovens. Radio waves generated from these appliances may cause unexpected problems in other electronic devices. We hope that the R&D performed at this research center will make it possible to keep visual track of the leakage of waves from electronic devices, which in turn will lead to clarification of the mechanisms by which electromagnetic interference (EMI) is generated. It is expected that these achievements will contribute to the enhancement of measures against EMI and to the creation of an environment in which people will be able to use all electronic devices in a safe and secure manner. Our R&D results are likely to find applications in a range of fields, from IC and board layouts to wiring pattern design.

REPORT

Report on Exhibition at European Conference on Optical Communication (ECOC2004)

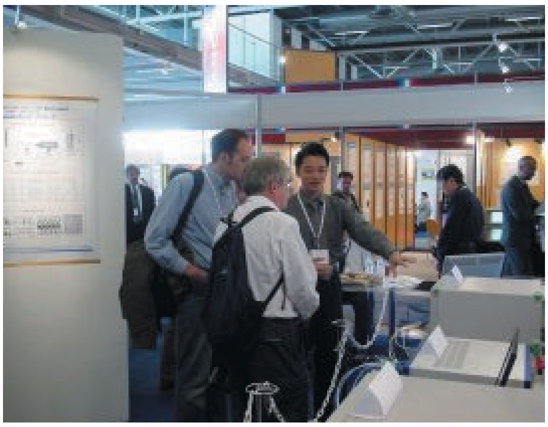
— Real-Time Demonstration of World's First Optical Packet Receiver and Packet Bit Error Rate Evaluator —

Naoya Wada
Senior Researcher, Ultrafast Photonic Network Group
Information and Network Systems Department



ECOC2004 exhibition hall


Real-time demonstration of optical packet transmission / reception and evaluation


Exhibition

The Ultrafast Photonic Network Group presented ten sets of research results and ran an exhibition booth at the 30th European Conference on Optical Communication (ECOC2004) held from September 5 to 9 in Stockholm, Sweden. The ECOC is the largest international conference on optical communications in Europe, and one of two major conferences of this kind in the world, the other being the OFC (Optical Fiber Communication Conference & Exposition) held annually in February or March in the United States. Industry, academia, and government researchers and managers from all over the world gather at the ECOC each year to present research results and exhibit the related devices. Reports on achievements in major EU-led projects are also highlighted. This year's exhibition drew more than 3,000 people.

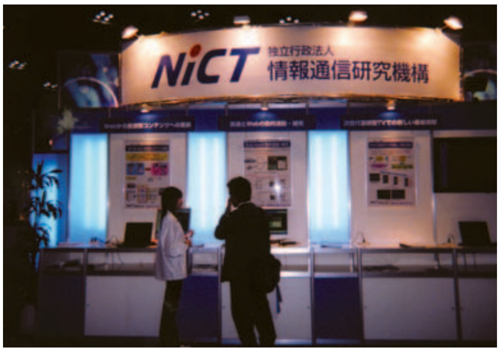
We presented ten research papers: seven on optical packet-switched networks (including one post-deadline paper and one by a guest speaker), and three on ultra-high-speed communications and related topics. At our booth, we exhibited newly developed devices and posters detailing the latest achievements. The devices consisted of an optical packet receiver and a packet bit error rate measurement system we developed last year in collaboration with two companies. The optical packet receiver offers a fast response time of 100 picoseconds or less, and the packet BER measurement system evaluates packet network characteristics at a rate of 40 Gbps. We performed a real-time demonstration of optical packet transmission/reception and an evaluation of characteristics. These devices incorporate practical-level technologies related to a state-of-the-art optical packet-switched network. We offered a visual presentation of the results of NICT's world-leading research activities, and received feedback through exchanges with researchers in related fields.

Our exhibition attracted interest from many people. We received questions and comments not only on technical aspects but also on the timing of commercialization, applications, costs, etc. I believe that this is partly due to the recent increase in system-based research, in addition to conventional basic experiments on optical packet switching functions. Professor Mike O'Mahony (University of Essex, UK), who is in charge of many EU-led projects, commented that it was amazing that NICT has elevated the latest conceptual-stage technologies discussed in technical papers to a practical level in such a short time, and also called attention to the dynamic display of these technologies. Although NICT is now the leader in this field, it's likely that many powerful competitors will appear in the future. We received a variety of comments and gathered valuable information through this exhibition and presentation of papers, all of which we intend to apply to the improvement of our research activities.

We would like to express our gratitude to the many people who provided their cooperation and assistance in the development of these devices and of this exhibition.

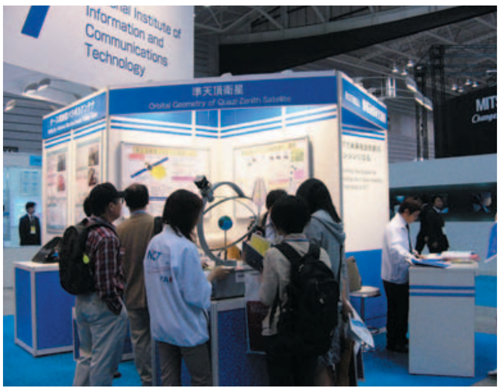
Report on Exhibition at Industry-Academia-Government Technology Exchange Fair, IAC2004 and JA2004

Public Relations Division,
General Affairs Department



Industry-Academia-Government Technology Exchange Fair 2004

IAC2004



JA2004

Since this is NICT’s first year, we’ve been participating in an exceptional number of external exhibitions–six in October alone. In this article, we report on three exhibitions held in the first half of October.

First, we attended the Industry-Academia-Government Technology Exchange Fair held at Tokyo Big Site from September 29 to October 1. This event had until last year been referred to as the International New Technology Fair; it was renamed and held on a larger scale this year to reflect the recent trend toward the promotion of exchanges among industry, academia, and government. We presented displays describing a framework of collaboration among industry, academia, and government, in addition to the actual results of research conducted in conjunction with various companies, to demonstrate NICT’s strong commitment to the promotion of this tripartite collaboration.

From October 4 to 8, the IAC (International Astronautical Congress) 2004 was held in Vancouver, Canada. This is an international academic aerospace conference, and is hosted in rotation by participating countries. In addition to conference sessions, enthusiastic participation was seen at exhibitions, workshops, and ceremonies. There were two exhibitors from Japan–NICT and JAXA (Japan Aerospace Exploration Agency), each with its own exhibition booth. The Wireless Communications Department exhibited a “Modular Robot for Space Operation,” a “Sub-millimeter Wave Limb Emission Sounder aboard the International Space Station,” and a “Free-Space Optical Communications Tracking System.” The Applied Research and Standards Department mainly used panels to display its “Development of Standard VLBI Board for PCs” and its “Space Weather Project,” conducted in collaboration with the government of Canada. Approximately 25,000 visitors attended over the course of the five days, most of whom were professionals in space-related fields from all over the world. Our researchers enthusiastically explained our exhibits to many of these attendees, all of whom showed a keen interest in NICT’s research results.

The third event consisted of the Japan International Aerospace Exhibition 2004 (Japan Aerospace 2004, or JA2004) held at Pacifico Yokohama from October 6 to 10. Gathering leading-edge technologies in one place once every four years, this is the only comprehensive international aerospace exhibition held in Japan. From NICT, the Wireless Communications Department and the Applied Research and Standards Department presented exhibits on seven subjects in total. Since the first three days (weekdays) were trade days, many professionals in related fields visited our booth. We were kept very busy taking care of these visitors, answering in-depth questions about NICT’s research activities. Many families attended on the public days (Saturday and Sunday). Actual helicopters and model planes were on exhibit at other booths, and many children could be seen enjoying the exhibition. With a total of about 110,000 visitors over the five-day period, JA2004 was a clear success.

We will continue to participate actively in external exhibitions to ensure that more and more people can learn about NICT’s activities and research results.