R&D Spirits

Creating Next-generation Wireless Networks

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The Wireless System Innovation Laboratory at NTT Network Innovation Laboratories is devoted to creating new wireless services based on the latest wireless technology and implementing next-generation wireless network services. But what role do wireless networks play in NTT's vision of a ubiquitous-communications-based future and what issues need to be addressed concerning this technology? We put these questions to Masahiro Umehira, the director in charge of research at the Wireless System Innovation Laboratory.

Researching Next-generation Wireless Systems to Support Ubiquitous Networks

—Dr. Umehira, could you summarize the R&D topics you are involved in at the moment?

At the Wireless System Innovation Laboratory, we are researching and developing next-generation wireless systems that will play a vital role in ubiquitous networks. There are three groups here, working on wireless systems, adaptive signal processing, and antennas. Overall, our work covers a wide range of fields from communication schemes to individual technologies such as antennas and circuits and applications to actual service using wireless technologies.

—What specific themes are you working on?

We are conducting a number of studies into broadband wireless systems from the viewpoint of improving their frequency utilization efficiency. Current broadband wireless systems can send up to only about 3 bit/s/Hz. This can be substantially increased by employing a technique called MIMO (multiple input, multiple output), and we are now working on an even more advanced technology called multi-user MIMO, which looks ready to make a significant breakthrough in wireless broadband technology. Multi-user MIMO technology is expected to achieve more than 20 bit/s/Hz, resulting in 1 Gbit/s wireless access with frequency bandwidth of 40 MHz (**Fig. 1**). We are also studying a 60-GHz-band wireless access system that achieves more than 1 Gbit/s, taking advantage of its significantly wide frequency spectrum availability.

In addition to the subject of broadband wireless systems, we are also researching technology for ubiquitous applications. This includes the concept proposal and system construction of a ubiquitous network that uses RFID (radio frequency identification) wireless tags to achieve new M2M (machine-to-machine, mobile-to-machine, and man-to-machine) services and the study of *ad-hoc* network technology that can freely configure networks wherever it is situated for purposes such as expanding public wireless local area network (WLAN) sites like hotspots and providing temporary network facilities in disaster areas.

As a separate technical study, attention is being focused on Software Defined Radio. This aims to enable wireless equipment to be used under software control in various wireless networks such as PDC (personal digital cellular) and wireless LAN networks in the same way that personal computers perform various tasks under software control. In a similar vein, we are also developing MMIC (monolithic microwave integrated circuit) chipsets for the sub-

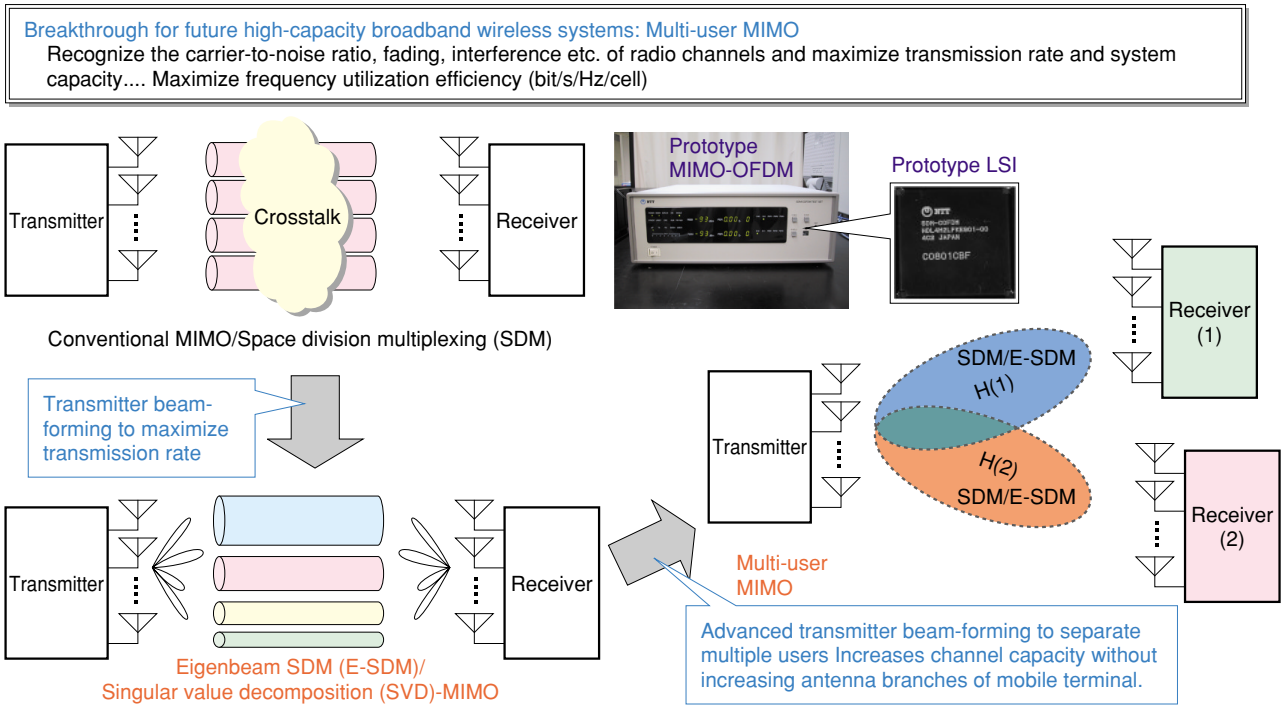

Fig. 1. Multi-user MIMO for future high-capacity wireless system.

millimeter band and are now on the verge of developing practical applications for this technology.

—What sort of impact will this R&D have on the world?

Wireless systems give people greater freedom. People often say that mobility is the greatest killer application of wireless systems, and I have to agree with that. Right now we're sketching out plans for ubiquitous networks where wireless technology is used to connect not only people but also a huge number of objects via tiny long-lasting terminals (**Fig. 2**). By using this new ubiquitous wireless network for a wide variety of applications such as logistical support, environment monitoring, healthcare, multiplexed communications, and remote meter reading, we hope to give people greater freedom and convenience in many different ways.

—What are the main technical issues involved in creating the next generation of wireless systems?

For wide-area ubiquitous networks, it's important to get signals to travel as far as possible with the minimum of electrical power. For this purpose, novel wireless network design including modulation, coding, and improved diversity is an important technical point to make it possible to receive weak signals reliably. Regarding broadband wireless systems, we aim to maximize the transmission capacity and system capacity by enhancing the base station systems, where multi-user MIMO is based on the same concept as this. As we enhance the antenna functions of base stations to improve their frequency utilization efficiency, we will make the mobile terminals operate faster to accommodate the needs of users. In addition to the above-mentioned future wireless technologies, we are conducting R&D of MMIC technologies to reduce the size and cost of current wireless terminals. Using MMIC technology, we have managed to integrate the circuitry into a 3-mm ultraminiaturized block where the circuits are stacked three-dimensionally like high-rise buildings. The reduced chip size allows us to achieve higher production yields, so it should also lead to lower costs. These developments should help to promote the introduction of wireless B-FLET'S services in places where optical fibers are difficult to install, such as sparsely populated areas and remote islands.

—And what will need to be developed and tackled in the future?

For wireless technology as a whole, I believe that would be how to make more effective use of frequen-

cy. This will always be a key issue for as long as we continue to use limited frequency resources. You always have to bear this in mind when conducting research and development in the field of wireless technology. Power supplies are another issue that must be confronted. For example, when wireless tags are commonplace, it would be a real nuisance to have to change each one's battery every time it runs out. So it is essential for tags to have batteries that carry on working until the tag has reached the end of its useful life. To provide batteries that last for 5 to 10 years, I expect we will have to work with power supply researchers while at the same time taking measures to achieve further power savings in our systems.

Efforts to Standardize Wireless LAN Technology in Japan, Europe, and the USA

—What is the current state of international activities related to wireless systems research?

On the international stage, we are mainly contributing to the standardization of wireless LAN technology. I was involved in the 5-GHz-band wireless LAN standardization in Japan and Europe. We proposed the OFDM (orthogonal frequency division multiplexing) technique to IEEE for IEEE802.11a and to ETSI-BRAN (European Telecommunications Standards Institute Broadband Radio Access Network) for HiperLAN/2. Meanwhile, Japan has set up the Multimedia Mobile Access Communication Systems Promotion Council (MMAC)—of which I am the chairman—and is moving ahead with the standardization of wireless LAN technology while establishing links with IEEE and ETSI. We are currently issuing proposals related to MIMO technology. Furthermore, looking further into the future, we are preparing to make active proposals for the 60-GHz band.

—Do you have any particular thoughts about the efforts being made at standardization?

In the period when I was involved in the standardization of a 5-GHz-band wireless LAN, we were active in MMAC of Japan, ETSI-BRAN of Europe, and IEEE802.11a of the USA. At that time it was strongly felt that wireless technology should above all be categorized according to frequency. That's because using the same frequencies in different countries makes it possible to keep costs down by using the same device components. It also means that the same terminal can be used anywhere in the world, which is a very important point.

Like real estate, frequency is a limited resource, so there is always fierce competition among carriers. For example, a big row broke out over a proposal to overlap wireless LAN frequencies with the 5.15–5.25-GHz frequency band used for communication

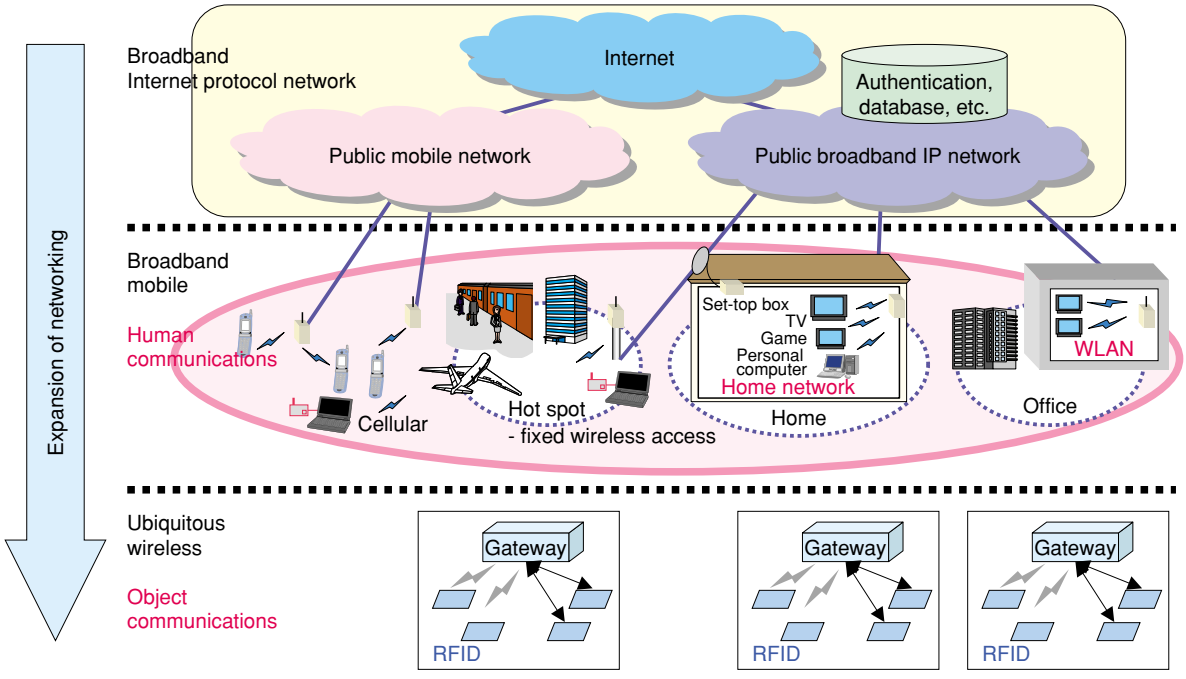

Fig. 2. Trend: Broadband + Mobile + Ubiquitous.

between satellite phone base stations and satellites. Therefore, to start a new service, the first thing you have to do is fight for a frequency allocation. Even at 100 MHz, there is plenty of international disagreement. This sort of problem probably never occurs in other fields of research. To use limited frequency spectrum resources as efficiently as possible, frequency alignment is also essential.

—Are you collaborating with any other research organizations or businesses?

Our dealings with other research organizations are mainly for the purpose of standardization. We are also collaborating with businesses on a case-by-case basis. Our research is ultimately aimed at NTT services, so it is sometimes difficult to release the achievements of individual technical studies. Since NTT is not a manufacturer, the circuits and devices we develop can't be turned directly into business opportunities. But on the other hand, this is no reason for us not to conduct individual technical studies. It's a matter of striking the right balance, really. So NTT develops individual technologies like MMIC that manufacturers are unable to work on. Then, we transfer this technology to manufacturers. That's our basic stance.

—In your experience, how is NTT Laboratories regarded abroad?

The members of NTT Laboratories work in many different academic committees, so I think they are acquiring good reputations to some extent on their own. In particular, we are proud to be regarded as one of the leaders in the field of wireless communication system technologies and antennas and microwave circuits. Although NTT is just a communications carrier, I think our reputation in the rest of the world depends on the sort of impact created by our new vision. That's because the uniqueness that NTT Laboratories shows to others derives not from individual technologies but from the way we propose new systems and concepts.

Battling the Forces of Nature —The Attraction of Wireless Research

—Incidentally, what would you say is your technical forte?

I've been working on wireless technology ever since I was a student. In fact I first got interested in how radios work when I was in the fifth grade of elementary school. I got drawn towards radio engineering after I built my own transistor radio. So even at graduate school I spent my time in the radio communication laboratory. That was the time when car phones had just appeared, so my studies concentrated on radio wave propagation and communication schemes for mobile communications. But I wanted to work on complete systems rather than their constituent technologies, so I joined NTT because I figured I'd have more opportunities to do that working for a communications carrier.

—What have you studied so far?

I joined NTT in 1980 (then Nippon Telegraph and Telephone Public Corporation) and started out working in the satellite communication equipment laboratory. In my first year I studied synchronization control schemes for SS-TDMA satellite communication, but the year after that I became part of a major research project launched to study large-scale satellite communications with the aim of building networks based on satellite communications and optical fibers. For several years I was mainly conducting R&D into modulation and demodulation methods for satellite communication. During that period I spent a year from 1987-88 as a visiting researcher in Canada at the Communications Research Center of the Department of Communications. Then, from 1993, I turned to research on wireless access technology, which is what I always wanted to study. Since then, I have been working on research into subjects such as wireless ATM (asynchronous transfer mode), OFDM, broadband wireless access systems like MIMO-OFDM, ubiquitous wireless systems for machine-to-machine communications, and software wireless technology. At the moment, I'm managing research on all aspects of wireless systems. It's now 25 years since I joined NTT, and although I've spent a bit of time involved in the research planning department I've spent the rest of the time working exclusively on wireless research. I am completely satisfied with my life as a reseacher.

—What draws you to wireless technology research?

From a purely technical viewpoint, I would say it's the modulation and demodulation technology used in signal transmission. When I was younger I studied all sorts of modulation schemes, and I even wrote my

Ph.D. thesis on the subject. I have also made various proposals in the field of standardization. And if you're asking what interests me about this field, then I guess it would be the ongoing struggle against the forces of nature. For example, in satellite communication, you have to figure out how to recover a stable signal by eliminating noise from the feeble unstable radio waves coming from a satellite 36,000 km away. In mobile communication, you have to deal not only with noise but also with fading caused by variations in the signal phase as the terminal moves. It feels good when you figure out how to overcome natural phenomena like these. The higher the hurdle is, the greater the feeling of satisfaction you get when you clear it.

—What sort of direction do you think research and development will take in the future?

From a management viewpoint, I think that although some individual technologies may disappear, it's important for us to set our course by keeping a close watch on the overall state of wireless technology. For example, several different modulation schemes have been used in wireless access technology, such as time division multiple access (TDMA) and code division multiple access (CDMA), but ultimately CDMA was chosen for 3G mobile phones. It is very hard to decide which out of several available technologies will be selected and kept in use. However, as a private-sector research establishment, we must continuously judge what will come next, taking into consideration factors such as originality and competitive ability. Younger researchers have a tendency to concentrate only on their own technology, so from my perspective it's important to make sure they see the bigger picture.

For example, single-carrier transmission has not been highly regarded for use in broadband mobile systems, but it can overcome the power limitation problem that is one of the weak points of current OFDM systems. In other words, since OFDM schemes use multiple carriers, a 100-W amplifier can output signals with a power of only 10 W or so each, but this sort of problem would never arise in a single-carrier system. So instead of sticking with OFDM systems, it might be worth using single-carrier systems instead. I think that this idea has actually been put forward. In fact, I'd quite like to try it out for myself. But these days, I can't do that sort of thing myself, so I'll mention the idea to some younger researchers.

Taking Wireless Transmission to the Extreme—A Researcher's Unfinished Dream

—What are your ultimate goals as a researcher?

Realistically, and considering all the organizations I'm involved in, I suppose my dream as a radio engineer would be to take wireless communication to the extreme and get rid of wires altogether. Recently, I've also become interested in cognitive radio[*1], which is a technology related to how frequency is used. Put simply, it is a technique for automatically detecting frequency bands that are not being used at a certain time and place and allocating them to carriers that want to use them. At present, applications are allocated to frequency bands on a regional basis, so for example a given band might be used for TV broadcasts in one region and for mobile phones in another. This might seem perfectly reasonable, but there are also many frequency bands that have been allocated but remain unused. Although these problems can be resolved by mutual agreement or by allowing market forces to prevail as they do in Europe, some carriers have run into trouble after investing vast sums of money to acquire bandwidth, so it isn't safe to simply rely on market forces alone. Cognitive radio might provide a solution to this problem. Of course, that doesn't mean that technology can solve everything: other measures such as legislation are also required. However, I think wireless research in the future must consider mechanisms that relate to the overall situation and not just individual technologies. In particular, from the viewpoint of making sure that frequency is used fairly and effectively, I think cognitive radio is a very desirable concept.

—What are your thoughts about NTT Laboratories?

As a place for doing research, it's almost ideal. There are always plenty of other experienced researchers around to help out, and from the outset you are given considerable freedom to study whatever you like. I'd be lying if I said everything here was exactly as I wanted it, but I really think this is just about the best environment to work in. In particular, I think it's great to be surrounded by people who you can bounce ideas off. Normally, researchers only get to discuss their work at conferences, but at NTT there are literally loads of top-notch researchers all around

*1 Cognitive radio: a term coined in 1991 by Joseph Mitola (see for example: http://en.wikipedia.org/wiki/Cognitive_radio).

you. And since their knowledge covers a wide range of fields, you can always find a specialist in any field you need to learn about. And another thing which I think is really important is that the researchers at NTT Laboratories are always prepared to discuss other people's ideas with them. This open-minded attitude makes for a very comfortable atmosphere at NTT Laboratories.

—And finally, what would you like to say to our younger researchers?

I'd like to ask them not to treat research as a 9-to-5 kind of job, but to experience what it's like to become so absorbed in research and development that you forget to sleep or eat. I often did that when I was younger. Maybe I wasn't the world's most efficient researcher, and perhaps the speed at which the telecom industry was growing back then was reflected in the research and development field. But aside from all that I felt a definite sense of mission, and I'm really glad that I did. I made a lot of good friends during that period. These days, telecommunications is becoming mature, so there is less virgin territory than there used to be. But it's the researcher's job to make breakthroughs. If you look hard enough, there ought to be plenty of new paths to go down, so I'd like to ask younger researchers to find one that they can devote themselves to—even if it means missing the occasional mealtime! That's why I think that managers such as myself should try to propose research themes that are very interesting.

Interviewee profile

■ Career highlights

Masahiro Umehira received the B.E., M.E., and Ph.D. degrees in electronic engineering from Kyoto University, Kyoto in 1978, 1980, and 2000, respectively. Since joining Nippon Telegraph and Telephone Public Corporation (now NTT) in 1980, he has been engaged in the R&D of modem and TDMA equipment for satellite communications, TDMA satellite communication systems, wireless ATM, and broadband wireless access systems for mobile multimedia services. From 1987 to 1988, he was with the Communications Research Center, Department of Communications, Canada, as a visiting scientist. He was involved in the European ACTS AWACS project from 1997 to 1998. He has been active in the standardization related to wireless ATM and wireless LANs using the 5-GHz band in Japan, Europe, and USA. He is now the Senior Manager of the Wireless Systems Innovation Laboratory in the NTT Network Innovation Laboratories, where he is responsible for the R&D of wireless technologies for next-generation fixed/nomadic/mobile wireless systems, future satellite communication systems, and ubiquitous services using RFID. He has been a guest professor at Niigata University, Niigata since 2004. He received the Young Engineer Award and the Achievement Award from the Institute of Electronics, Information and Communication Engineers of Japan (IEICE) in 1987 and 1999, respectively. He also received the Education, Culture, Sports, Science and Technology Minister Award in 2001 and the TELECOM System Technology Award from the Telecommunications Advancement Foundation in 2003. He is a member of IEEE and IEICE.