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Technology and Policy Trends in Frequency Sharing


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1 Introduction

We are using wireless technology more and more in our daily lives. Already, the number of mobile telephone subscribers exceeds the number of landline telephone subscribers. Wireless local area network (LAN) equipment is now standard on personal computers. The new application of electronic toll collection systems (ETCs) has also begun to spread through the market.

In order to utilize wireless technology, frequencies must be established. If a certain frequency band is in use and the same band is utilized for another purpose at the same time, interference will result. Based on the idea that authorities should designate the users of each of frequency band in order to avoid interference, since the 19th century governments in every country have managed the use of frequencies.

Once use of a given frequency is authorized, users purchase wireless equipment and begin using it. This imposes an economic burden, so it is difficult to cancel such authorization once it has been given. Those who desire new frequencies are therefore pushed into high frequencies. However, the higher the frequency, the more linear the wireless transmission (radio waves) and thus the shorter the range, making usage difficult.

In order to provide easy-to-use frequencies in response to exploding demand, a new movement to share frequencies is being born. This article will discuss trends in technologies and policies related to such frequency sharing.

2 Exploding wireless demand and frequency management

In Japan, the number of mobile telephone subscribers passed the number of landline subscribers in the spring of 2000. That trend subsequently continued, and as of the end of March 2004, the number of home and business landline subscribers was 50.94 million. In contrast, at 81.52 million, the number of mobile telephone subscribers, including Personal Handyphone System (PHS) subscribers, was 30 million higher.

People have also invented another wireless device: wireless LAN. Wireless LAN is becoming standard equipment on personal computers. It can also be used to connect with televisions and peripheral devices. Along with this, the market has rapidly expanded. According to Nikkei Communications (December 22, 2003), the 2003 market size was ¥48.4 billion, a 28 percent increase over the previous year.

The Japanese Government is promoting the e-Japan Program. The latest version of the program, e-Japan Priority Policy Program-2004, sets forth a policy of using wireless technology to aim for the achievement of ubiquitous networks enabling connection “anytime, anywhere, by anything.” “Ubiquitous” means “anytime, anywhere.” There is a great difference both in feeling and in performance between radio-cassette players that have to be plugged in and mobile music players. Equipment for

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Table 1 : Two frequency control methods and their features

	Frequencies requiring licenses	Frequencies not requiring licenses
Example	Television broadcasts: 90-108MHz, 170-222MHz, 470-770MHz	Bands for industrial, scientific, and medical uses: 2400–2500 MHz (Shared by wireless LAN, microwave ovens, medical devices, etc.)
	Mobile telephones: 810-850MHz, 860-901MHz, 915-958MHz, 1429-1453MHz, 1465-1468MHz, 1477-1501MHz, 1513-1516MHz, 1920-1980MHz, 2110-2170MHz	
Designation of users	• Licenses are given to specific entities based on screening	• Freely used, without licensing
Management of usage conditions	• Purpose of use, technologies, wireless output, etc., are all regulated.	• Regulated to have 10mW or less of output
	• Managed by inspection	• Managed at the factory shipping stage

Source: Authors' compilation based on Ministry of Internal Affairs and Communications materials[1].

"anytime, anywhere" use will be achieved by moving towards replacing wired connections to communications networks with wireless.

Further movement towards the use of wireless technology can be expected. On the other hand, however, because of the problem of interference in wireless communications, frequencies are considered a "scarce resource" and they have been carefully controlled by governments.

In contiguous countries such as those in Europe, wireless spills over national borders. To avoid negative impacts from this, international principles for frequency use are set by the International Telecommunication Union (ITU). Based on those principles, each national government allows the use of individual frequencies. Thus, a twofold national-international regulatory structure is in place.

Following Marconi's invention of wireless transmission in 1885, in 1906 the International Radiotelegraph Convention was organized, and its combination with the International Telegraph Convention in 1932 led to the current ITU. In Japan, the Wireless Transmission Law was passed in 1915, and after World War II, in 1950, it was revised into the Radio Law. Under that law, with some exceptions, "those who would open a wireless station must receive permission from the Minister of Internal Affairs and Communications." Government control is taken for granted.

Wireless LAN is an exception. It uses special frequencies called unlicensed bands. Table 1 shows a comparison with areas where licenses are needed, and the different ways they are controlled.

The problem is that the majority of frequencies require a license, and unlicensed bands are few.

In Table 1, we can see that television is broadcast over bandwidth totaling 370 MHz, but bandwidth for industrial, scientific, and medical uses are even narrower at only 100 MHz. Moreover, there are frequency gaps between the channels of television broadcasting, so there is extra room within the frequency bands occupied by television broadcasting services. Meanwhile, the bandwidth utilized for wireless LAN is tightly packed and is already approaching its limits. The government is attempting to shrink the frequency bandwidth used by television broadcasting by switching to digital. However, it will take some time before that shift can be completed.

It is questionable whether exploding wireless demand can be met merely through continued strict government regulation. With that as the greatest point of debate, various countries are now reviewing their policies.

3 Trends in spectrum policy

3-1 Establishment of the SPTF in the United States

In the United States of America, the Spectrum Policy Task Force (SPTF) was organized in June 2002 according to the instructions of Federal Communications Commission (FCC) Commissioner Michael Powell. The mission of the SPTF is to examine the proper state for spectrum policy[2].

In the United States, frequencies utilized by the military have the highest priority. As a result, frequencies for the third-generation mobile phones that have spread so remarkably in Japan cannot be designated, and the opening of services

Table 2 : Proposals for drastic reform of spectrum policy (Summary)

i) In the past, attempts to make full use of bandwidth were limited by interference. With advances in technology, however, that is no longer a problem, and new systems with more efficient spectrum use are now possible.
ii) However, continuing the traditional system of spectrum regulation through the granting of licenses will limit users in many bandwidths.
iii) Spectrum regulation should be reformed in the direction of greater flexibility and market orientation.
iv) From the perspective of preventing interference, a new regulatory model should be constructed by clearly defining the rights and responsibilities of licensed and unlicensed users (users of the spectrum commons who do not need licenses, as with wireless LAN).
v) A single regulatory model should not be applied to all frequency bandwidths. Systems for exclusive allocation of bandwidth based on market principles and for the creation and free use of spectrum commons should exist alongside the traditional licensing regulatory model.
vi) New regulatory models should be applied not only to new frequencies, but also to already distributed bandwidth. A mechanism should be created for migration of the latter from the traditional regulatory system.

Source: Authors' compilation based on SPTF materials.

has been delayed. On the other hand, use of wireless LAN is greater than in Japan. These kinds of situations led to the formation of the SPTF.

The SPTF submitted its first report in November 2002. At the front of the report, it says, "While the Commission has recently made some major strides in how spectrum is allocated and assigned in some bands, principally through flexible rules and competitive bidding, spectrum policy is not keeping pace with the relentless spectrum demands of the market. The Task Force has begun the process of reexamining 90 years of spectrum policy to ensure that the Commission's policies evolve with the consumer-driven evolution of new wireless technologies, devices, and services."

Competitive bidding is the system of allowing the communications company that submits the highest bid to utilize a given frequency for a given use. In the U.S., competitive bidding was used in 1994 to determine the frequencies for the Personal Communication System (PCS). Subsequently, frequencies for third-generation mobile telephone systems were put up for competitive bidding in the United Kingdom and Germany. Awarding bandwidth to the highest bid invites the participation of enterprises that are aware of the risk and will utilize the frequencies. This is also called market-driven or market-based allocation of bandwidth.

The SPTF's concrete proposals are summarized in Table 2.

For example, in regard to wireless used for military purposes, it is appropriate for government to use its power to designate frequencies, as has been done for the past 100 years. On the other hand, fields where numerous vendors want to participate, such as mobile telephone systems, are opened to competitive bidding. In part, a shared area called a spectrum commons could be set up. This is the basis of the idea of having multiple regulatory models coexist.

"Commons" usually refers to shared land. In Japan, the concept dates far back in the idea of "right of common." The right of common is a common-law right codified in civil law as the right of residents to jointly use trees and brush from designated forested mountains and fields (commons) for firewood and so on.

The question is, which residents can enter the commons and harvest trees and brush for firewood. If people try to exercise their rights by harvesting too much, it becomes a serious problem for everyone else. Moderation in harvesting is required. In the case of a spectrum commons as well, anyone can use it. However, if someone therefore decides to recklessly boost wireless output, it will interfere with other communications. This commons therefore also requires moderation. Wireless LAN is a technology that utilizes a spectrum commons, and thus it must be used responsibly so that all can utilize that shared asset.

FCC Commissioner Powell immediately expressed agreement with the SPTF's recommendations.

Following the SPTF report, in June 2003 U.S. President George W. Bush announced the

Table 3 : Proposed spectrum policy reforms in Radio Policy Vision (Summary)

i) Quickly prepare a system for the reallocation of spectrum through an examination of spectrum use and an announcement of the results, as well as the creation of a payment system to compensate incumbent licensees for economic losses.
ii) **Because competitive bidding may lead to sudden jumps in bid prices, create a transparent and fair comparative examination method to establish transparency in spectrum use.**
iii) Increase spectrum allocation flexibility by expanding low-watt spectrum commons for unlicensed stations along with allocating unique regional frequencies.

Source: Authors' compilation based on Special Department for Radio Policy materials.

opening of the Spectrum Policy Initiative (SPI). Headed by the Secretary of Commerce with the FCC also participating, the SPI is a venue for policy discussion. In these ways, the United States is beginning drastic reform of its spectrum regulations.

Even as those discussions continue, the FCC is already working to adopt new regulatory models from the perspective of frequency sharing.

In June 2004, two technologies for low-earth-orbit satellite communications, code division multiple access (CDMA) and time division multiple access (TDMA), were approved to share the 1.6 GHz band. How the sharing is to be achieved was left to discussions among the communications vendors who will use each technology. This action was based on the intent of minimizing government intervention.

To more efficiently utilize licensed frequencies, in July the U.S. government moved to create a "secondary market" intended to create a mechanism allowing license holders to lease their frequencies to others. If the competitive bidding markets described above are "primary markets," the leasing to others at "market prices" of the frequencies thus obtained comprises "secondary markets."

Another startling proposal, the utilization of open channels below 900 MHz on the television broadcasting frequency band for wireless broadband service, was set out in May 2004 (FCC DA 04-341). We will address this again later in the article.

3-2 Japan's Radio Policy Vision

In Japan, the Special Department for Radio Policy of the Information and Communications Council has carried out activities similar to those of the SPTF.

The Department held its first meeting in September 2002. It submitted its final report in July 2003. Entitled "Radio Policy Vision," the report offered the proposals summarized in Table 3 regarding the redistribution and allocation of spectrum[3].

The direction of the report shares with the United States the idea of expanding the spectrum commons. In contrast to the United States' assertion of market principles, however, the report asserts some Japanese ideas, such as problems associated with competitive bidding. This is a major point of debate. However, since comparative policy is not the purpose of this article, we will not discuss it further.

Subsequently, in August 2004, the Ministry of Internal Affairs and Communications announced an action plan to smoothly and steadily reorganize spectrum based on an evaluation of usage of frequencies of 3.4 GHz and above. Regarding the 3.4 to 3.6 GHz frequency band, for example, the action plan says, "Currently, it is used for video and audio communications, but because it is suitable for mobile communications, shifting audio to other frequency bands will be examined." In addition, regarding the frequency band from 5.25 to 5.85 GHz, the plan notes that it is used for ship and weather radar and expresses the view that it is "suitable for spectrum sharing with wireless LAN."

In these ways, the Ministry of Internal Affairs and Communications is moving towards achieving the recommendations of the Special Department for Radio Policy for spectrum reorganization and commons expansion.

Furthermore, the government announced that frequencies in the 800 MHz band would be reallocated for third-generation mobile telephone use and called for opinions in August 2004. The sight of some communications vendors objecting to the plan for reallocation mainly to existing mobile phone companies was striking.

As we have described, in both the United States and Japan, policies are underway to share spectrum and utilize it as a commons. In the next section, we will discuss relevant technology trends.

4 Development trends in frequency sharing technology

In this section, regarding technology trends related to wireless systems, we will outline those technology trends particularly responsive to effective spectrum use. The literature points to (1) reorganization of spectrum in the 5GHz band and (2) the adoption of new ultra wideband wireless systems as important fields for research and development from the perspective of effective spectrum use[4].

(1) is R&D related to advanced wireless LAN. It brings the functions of the Internet to wireless systems. (2) is ultra wideband wireless systems (UWB). Communications systems have hierarchical structures. UWB technology provides a physical communications environment for the transfer of digital data, including audio. Expectations are high for UWB as a new platform.

Although we will not discuss it further in this article, the realization of such new services will require not only wireless technology, but also the simultaneous resolution of issues related to ensuring quality of service (QoS), arrangement of terminals, proper routing, and security.

4-1 The position of frequency sharing technology in wireless LAN

(1) Overview of wireless LAN technology

The United States Institute of Electrical and Electronics Engineers (IEEE) has studied and standardized technology for the reorganization of the 5GHz band for effective frequency use. Since there was worldwide participation in that standardization, it is seen as the international standard as well.

Wireless LAN is a type of local area network (LAN) technology. Systems have to meet the physical and equipment standards of the Internet protocol (IP) for data transfer.

Table 4 : Working groups in IEEE 802.11, 802.15, and 802.16 committees (part)

Working group		Study areas
TG11	a	Physical layer of 54 Mbps via 5GHz band OFDM
	b	Physical layer of 11 Mbps via 2.4 GHz band CCK
	c	Extension of 802.1D bridge specifications to 802.11
	g	Physical layer of 54 Mbps via 2.4 GHz OFDM
	i	Enlarging security
	j	Specifications for Japan's 4.9 GHz standard
	n	Next-generation wireless LAN
	p	High-speed mobile systems appropriate for trains and DSRC
TG15		Standardization of local area network PAN specifications
TG16		WiMAX, standard for licensed frequencies in the 2–11 GHz band

Source: Authors' compilation based on IEEE materials.

Wireless LANs can be constructed not only in offices, but also in specified locations (hotspots) in commercial areas and so on. The technology has even advanced to the point of communications control for mobile computers and other terminals. Against the backdrop of increasing demand for development of this wireless LAN technology, both Japan and the United States are moving towards deregulation as optimal for spectrum regulation.

(2) IEEE 802.11 standard and areas of application

The IEEE's 802 Committee is a working group that carries out everything from study to standardization of elemental technologies. Table 4 shows some of the standardization work performed by subordinate organizations of the 802 Committee. The chart shows not only 802.11, but also 802.15 and 802.16[5].

(3) Frequency sharing in wireless LANs

When many users utilize a wireless LAN in the same location, there is a danger that interference may occur. Carrier sense is a technology to avoid this problem.

In wireless LAN (802.11b), a maximum of

14 20-MHz channels can be set within a 2.4 GHz band. Three of those channels may be used simultaneously. Before data is transmitted, "carrier sense" scans for open channels, and then an open channel is used. This is carrier sense multiple access with collision avoidance (CSMA/CA), which prevents interference.

In addition, rules for allocating the timing of radio-wave retransmission and for orderly resending when transmission fails, in other words, a wireless access protocol, have also been set.

In the case of wireless LAN, data is transmitted in "bunches" called "packets." The length and cycle generated differs with each transmission, so it is the proper assembly of packets and efficient response that enable the transmission of high-speed multimedia.

4-2 WiMAX and overlay

The widely disseminated wireless LAN is a technology for transmission over a range of a few meters to a few tens of meters and is therefore designed for use in homes and offices. In contrast, worldwide interoperability for microwave access (WiMAX) is a wireless technology being developed for use over a range of a few kilometers.

As seen in Table 4, the IEEE is working on the standardization of WiMAX technology, which is called 802.16 technology after the committee in charge of its standardization.

802.16a was released in January 2002. Work on the creation of standards for an upgraded version is underway.

Table 5 shows an overview of the 802.16a standards. If bandwidth is 20 MHz as shown in Table 5, at 5 MHz per channel with a maximum speed of 75 Mbps, a transmission speed of 15 Mbps can be achieved. Thus, it is suitable for services somewhat faster than an asymmetric digital subscriber line (ADSL). Although ADSL advertises a speed of at least 40 Mbps, that is a nominal value. At a distance of one kilometer or more from a station, a speed of no more than a few Mbps can be expected.

Various companies are already working to develop products that comply with the WiMAX standards. The first products are expected to reach the market in 2005. In addition, although WiMAX is a technology for fixed communications, improvements to enable its use with mobile communications have begun.

Table 5 : Overview of WiMAX (IEEE 802.16) standards

Frequency bands	<11GHz
	2.5, 3.5GHz (licensed)
	5.8GHz (unlicensed)
Transmission speed	75 Mbps maximum
	(20 MHz bandwidth)
Usage configuration	Fixed (outdoors/indoors)
Cell size	6–10 km radius (Maximum distance 50 km, depending on tower height and location)

Source: Authors' compilation based on Intel Corp. materials[6].

In connection with WiMAX, study of "overlay" has also begun. This is a mechanism for allowing other users to utilize wireless on frequencies where there are already licensed users. It can be seen as a technology similar to CSMA/CA. This article looks at WiMAX because there is a movement to apply overlay to WiMAX.

The main targets of overlay technology are the frequency bands used for television broadcasting. Television broadcasting has many unused channels. The open channels vary by location, so it is proposed that they be dynamically detected and utilized. Even if a given frequency were being used by the licensee, carrier sense would detect it and instantly move to another frequency. Thus, interference would not be a problem.

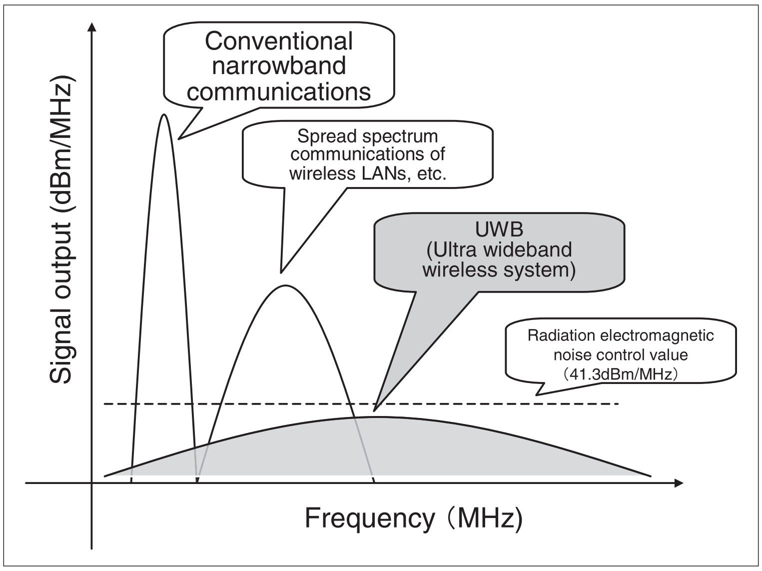
Because the technology has the "brains" to automatically detect open channels this way, it is sometimes referred to as "smart" or "agile" wireless. Some groups call technology that effectively utilizes unused frequencies "recognition wireless." The name has not yet become fixed.

Television broadcasting frequency bands are being used for two-way data transmission and Internet access. As we described above, the FCC has begun seeking opinions on the use of overlay. Manufacturers have performed demonstrations with devices built with such technology.

4-3 Spread spectrum communication and UWB

Ordinarily, wireless communications use

Figure 1 : The principles of an ultra wideband wireless system



a narrowband system. Many readers have experienced turning a tuner (radio dial) and seeking a band where there is a signal. When the tuner matches a carrier wave frequency, a clear signal is obtained.

In spread spectrum communication, on the other hand, signals are spread across a broad width of 100 MHz or more. At the same time, the radio waves (signal output) on each frequency are weak, so wireless devices pick them up only as noise. Thus the communication is concealed.

Figure 1 shows an overview of the relationship between the frequencies used and strength of signal. Spread spectrum communication with its bandwidth widened to the extreme is UWB, as illustrated in the chart. The "radiation electromagnetic noise control value" in the chart is the value at which other wireless devices can receive it only as noise. Below that value, conventional narrowband communications will be completely undisturbed, so coexistence is possible.

The technology of spread spectrum communication was patented during World War II, in 1942. However, partly due to the times, a way to use the patent was not found. Subsequently, development of spread spectrum communication proceeded only with military applications in mind.

Only in 1985 was the technology first tested by being used in the personal computer interface Recommended Standard 232 C (RS-232C). Although it was not a commercial success by any means, civilian use of the technology was accelerated after that.

An example where it is widely used is in musical instruments used in concerts and so on. Musical Instrument Digital Interface (MIDI) uses spread spectrum communication for its wireless connections.

In wireless communications, signals output below the noise threshold do not disturb other devices. As we explained above, using this small signal output is the first point of spread spectrum communication.

Next, let us consider what happens when two or more spread spectrum communications are used at the same time. Encryption is used to avoid interference at that time. Encrypting data to be sent so that the contents do not leak to the wrong recipient is the second point of spread spectrum communication.

If we use the analogy of a party with international guests, languages such as English, Japanese, and Chinese, might be flying about the venue. Korean might be spoken right next to French. However, as long as no group breaks out in loud voices and intrudes on the others, conversations will not be interrupted. The limit of an acceptably loud voice is like the first point, the radiation electromagnetic noise control value. The different languages are like the second point, the encryption in spread spectrum communication. If a language cannot be understood, a conversation in that language cannot be understood either. If a number of encryptions are set and different ones are used, multiple communications can be separated.

In this way, spread spectrum communication can be used to allow different types of wireless communications to coexist.

CDMA technology has developed based on spread spectrum communication and is utilized in third-generation mobile telephones. In addition, spread spectrum communication will also be used in wireless LAN.

Furthermore, UWB technology has been in the spotlight, and R&D to put it to practical use is progressing. In part this is because the FCC approved limited sales of UWB products in February 2002.

In May 2004, an international conference on UWB was held in Kyoto. It was observed that a speed of several hundred Mbps was announced, and that an LSI chip set to support it would go on sale for about $10 next year.

Once a chip set is completed, making a small device will be simple. USB memory, tiny devices equipped with flash memory and a universal serial bus (USB) terminal inside are used as backup personal computer memory. In the same way, if a chip set is added to a small container with a USB terminal, UWB can easily be substituted for the personal computer communications process.

A newspaper reported that the National Institute of Information and Communications Technology, an Incorporated Administrative Agency, will undertake the development of practical UWB technology (Nihon Keizai Shimbun, October 22, 2004). Japan has also begun full-fledge R&D.

5 R&D and policy recommendations

The technologies mentioned here are only a small part of the wireless systems that can be expected to develop and spread from now on. Research and development in the field is multifaceted, with many new R&D needs appearing. Here we will touch on some important points regarding research and development in this distinctive field.

(1) Characteristics of wireless technology

Only when spectrum can be used does wireless technology become practical. From another perspective, if spectrum appears unlikely to become available in the future, resources for development will not be invested. In this way, spectrum policy has a major influence on wireless technology research and development. In the field of information communications, the direct influence of government policy on technological development is a unique characteristic of wireless technology.

As we mentioned at the beginning of this article, wireless technology is one of the keys to achieving a society with ubiquitous network connections. To further the development of this wireless technology, it would be effective if policy authorities were to show a concrete direction for technologies such as overlay technology and UWB technology.

An aggressive review of technology policy supporting wireless technology research and development in light of changing technology should be performed in connection with regulatory policy. For example, if the UWB technology described above becomes widely used, the traditional regulatory concept of "specific systems must be licensed to use specific frequencies" will no longer be useful. New regulations should look to the output of wireless devices, and regulatory policy should shift from regulation of frequency bands to regulation of radio-wave output. Research and development will follow this as it progresses.

Wireless is not the only technology field where policy needs to be comprehensively reexamined to promote R&D of frontrunners. In any field, policy should be proposed in light of the characteristics of new technological factors.

(2) Research direction and role clarification

At an international conference on communications during the mid-1990s, when mobile telephone use was rapidly expanding, a researcher in wireless communications said, "At last it sees the light of day." Those words brought home the importance of continued general, basic research. Basic research connected to the fostering of human resources at the graduate level is at the root of the accumulation of broad knowledge, from modulation and other communications engineering basics to Internet communications methods to standardization to forms of computer terminal use.

University professors play a leading role in the above-mentioned wireless technology research of the National Institute of Information and Communications Technology. The leader of the special group on UWB, for example, is Professor Ryuji Kohno of Yokohama National University. The Institute's basic research is being watched as a test of linking basic research to practical application.

At the same time, R&D with an awareness of marketability is needed in fields where new applications appear in a short time. Competition for business hegemony in wireless systems is particularly fierce, and the capture of marketability at the final stage of R&D is strongly required.

It is therefore important that the R&D that should be carried out by universities and public institutions and that which should be actively performed by private sector enterprises be clearly divided so the most appropriate forms and goals can be laid out.

(3) Deregulation and the promotion of research and development

At the stage of providing wireless technology for actual use, preparation of an environment for practical testing is important. In Japan, a separate license must be obtained in order to perform outdoor experiments. Such licenses are issued only with very detailed conditions, for example, "At the aforementioned frequency, a test for other radar will be performed for one minute. If it exists, radio waves will be turned off within 10 seconds." Such regulations prioritize protection of those already using frequencies and form an obstacle to R&D.

One idea is to utilize outlying islands with a population of a few thousand as special wireless zones. Such zones already use mobile telephones, fishing radios, and so on, so they could be utilized to test whether new systems disturb existing ones. Compared with urban areas, the damage would be minimized if any problems should occur. If such experiment environments are created, wireless device manufacturers would build permanent testing facilities and universities with telecommunications programs would place labs there. This would bring economic benefits to the special zones.

In the United States, outdoor experiments are already actively conducted on indigenous peoples' lands and other places where impact is light. Japan also needs to prepare environments for wireless experiments through measures such as the utilization of special zones.

References

[1] Ministry of Internal Affairs and Communications, "The Radio Use Website,": http://www.tele.soumu.go.jp/index.htm

[2] Information on the Spectrum Policy Task Force is available at: http://www.fcc.gov/sptf/

[3] Special Department for Radio Policy, Information and Communications Council, "Medium- to long-term outlook of radio spectrum use and the role to be played by government: Radio Policy Vision," : http://www.soumu.go.jp/s-news/2003/030730_5a.html

[4] Information Processing Society of Japan, "Construction of an Internet using wireless LAN technology", Jouhou Shori, vol. 45, No. 8, (August 2004) (in Japanese)

[5] IEEE website: http://www.ieee.org

[6] Intel Corp. website: http://www.intel.co.jp

(Original Japanese version: published in November 2004)