Spectrum Management of DSL Systems in Japan

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***Abstract*— The Japanese broadband market is maturing due to expansion in the needs for richer IT lifestyles with higher bit rate access. DSL technologies have played an important role in such growth because of their lower cost and ease of deployment. In order to expand the coverage area and compete with faster services such as FTTH, the DSL family of technologies is diversifying, and there are various services on the market currently in Japan. It is very important to manage those different kinds of systems in order to minimize interference due to crosstalk. This paper describes the Japanese spectrum management standard put into effect this year.**

I. Introduction

The advent of broadband technologies has dramatically increased the popularity of the Internet in Japan. A major driving force has been DSL (Digital Subscriber Line) technologies, which have the advantage of low cost and ease of deployment since those technologies use the existing metallic cable infrastructure. In addition, the competition for customers among service providers has rapidly intensified, which has further brought down the market price. As a result, the DSL market has achieved rapid growth. The number of DSL subscribers has risen to 13 million as shown in Fig. 1.

On the other hand, although there was a steady increase in the number of DSL subscribers until the end of 2002, since then subscription has continued to decline, as shown in Fig. 2. This tells us that the market of potential users for whom DSL is available has almost become saturated, and at the same time user needs have now shifted toward much faster Internet access technologies such as FTTH. Currently, many people want to have the so-called "triple play" of services, or online video, Internet and voice services, requiring higher speed Internet access not only in the downstream but also the upstream direction. In order to retain existing customers and also forge a new market, DSL service providers have begun to provide new systems with highly upgraded performance.

Extending the bandwidth is one way to achieve higher speed access easily. Most DSL service providers in Japan deployed such extended systems to upgrade their services to 40-50Mbps downstream and 3-5Mbps upstream. This move, however, progressed too quickly, and those extended systems were proprietary to the providers, with little standardization, resulting in various systems being deployed in the market.

However, expansion of those bandwidths without limit may cause interferences between different systems deployed in the same cable. For this reason, it is very important to manage those different kinds of systems in order to minimize interference due to this crosstalk. To further develop DSL services in Japan, the spectrum management standard [2] has recently been updated. This paper describes the basic idea of spectrum management in Japan and the changes made by the new standard put into effect this year.

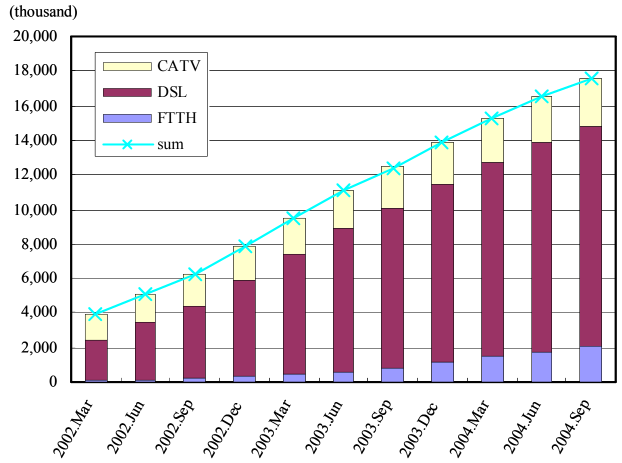


Figure 1. Transition of broadband Internet users in Japan since 2002. Data from the Ministry of Internal Affairs and Communication of Japan [1].

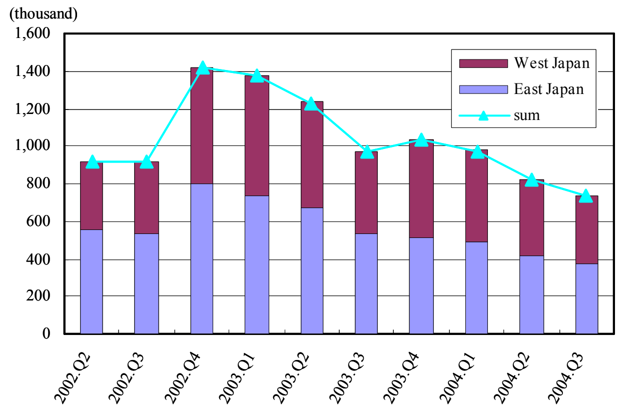


Figure 2. Transition of increase of DSL subscribers for each quarter. Data from the Ministry of Internal Affairs and Communication of Japan [1].

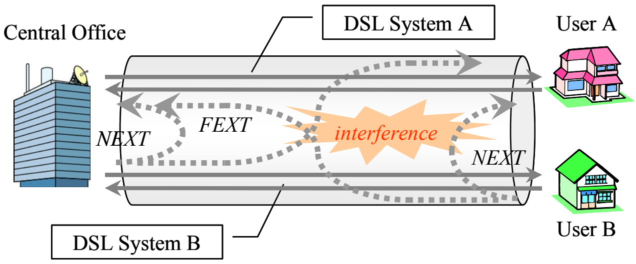


Figure 3. Interference due to crosstalk from NEXT (near end crosstalk) and FEXT (far end crosstalk).

II. SPECTRUM MANAGEMENT

DSL technology uses metallic cables for public telephone. Different DSL systems transmitting over loops in the same cable always generate crosstalk among each other, as shown in Fig. 3, which is a major issue for DSL service providers. The more DSLs deployed, the more crosstalk there will be. If only one provider offers DSL service, that provider has only to be responsible for the spectral compatibility of its own service. However, deregulation made it possible for many providers to launch broadband Internet access businesses over the same metallic cables. Thus, competition among service providers made it necessary to standardize spectrum management for DSL systems.

There is no international standard for spectrum management since the characteristics of local loops and their uses are different for each country. In the USA, the T1E1.4 Committee created their own requirements for spectrum management called ANSI T1.417-2003 [3], and ETSI is in charge of the establishment of standards in Europe.

In Japan, the Ministry of Post and Telecommunications (now the Ministry of Internal Affairs and Communications) established a study project on high speed digital access technologies in 1999. Now, the Telecommunications and Technology Committee (TTC) takes on the task of creating a technical definition on DSL spectral compatibility. The first issue of Japanese spectrum management, called JJ-100.01, was published in November 2001. It was updated in the second issue two years later, and the current third issue was released in March 2005 [4].

The purpose of spectrum management is to minimize interference between different DSL systems while allowing multiple providers to competitively offer various broadband services. For this purpose, the JJ-100.01 standard defines the acceptable level of degradation from crosstalk between each DSL system and ensures spectral compatibility. Under the standard, all providers share the responsibility for spectrum management.

III. BASIC CONCEPT OF JJ-100.01

First, in JJ-100.01, transmission systems are classified into four classes based on whether they are guarded from any other system and whether there are deployment restrictions applied, as indicated in Table 1.

TABLE I. CLASSIFICATION OF TRANSMISSION SYSTEMS IN JJ-100.01.

	protected	not protected
no deployment restriction defined	Class A	Class B
some deployment restrictions defined	Class A'	Class C

TABLE II. LIST OF CLASS A SYSTEMS. FROM ISSUE 3 OF JJ-100.01, G.992.1 ANNEX I DBM (FDM) WAS DEEMED A CLASS A SYSTEM DUE TO ITS POPULARITY IN TERMS OF DEPLOYMENT IN THE JAPANESE MARKET.

1	Voice Service
2	TCM-ISDN (G.961 Appendix III, JT-G961)
3-1	G.992.1 Annex A (FDM)
3-2	G.992.1 Annex C DBM (FDM)
3-3	G.992.2 Annex A (FDM)
3-4	G.992.2 Annex C DBM (FDM)
3-5	G.992.1 Amendment 1 Annex C profile 5 (XDD)
3-6	G.992.1 Amendment 1 Annex C profile 6 (XOL)
3-7	G.992.1 Annex A (sOL) class A version
3-8	G.992.1 Annex I DBM (FDM)

No restrictions for deployment are in place for Class A systems. Table 2 shows a list of those Class A systems, including voice service. G.992.1 Annex I DBM (FDM), which enables 24 Mbps downstream, was newly appended to the list in JJ-100.01 Issue 3 because the number of cases of its deployment had reached almost one million.

Class A systems are provided with reference performances, as shown in Table 3, defining allowance limits from other systems. Reference of G.992.1 Annex A (sOL) is represented by that for G.992.1 Annex A (FDM). G.992.1 Annex C DBM (FDM) stands for references of G.992.1 Amendment 1 Annex C profile 5 (XDD) and profile 6 (XOL) and G.992.1 Annex I DBM (FDM). Grouping in this manner helps to simplify the spectral compatibility verification process in demonstrating calculated compliance of new systems with the protected systems. The table is derived from a computer-simulated calculation of their interference level in a statistically worst-case scenario. Any other new technology introduced must not degrade transmission performance of Class A systems. They are protected up to 1.104 MHz in the sense that the representatives in the reference performance table use frequencies up to 1.104 MHz.

Using the tables shown here, spectral compatibility is checked with the following two methods:

A. *Limiting Signal Power*

Each DSL system has a specific power spectral shape defined by its PSD (power spectral density). Spectral compatibility is established when a PSD is confirmed to be below some defined PSD mask at all frequencies, the compatibility of which had already been proved. In addition, the total transmission power also has to meet the regulations.

B. Calculating Compliance with Class A Systems

Another method of checking spectral compatibility is to calculate compliance with the "protected" systems defined as Class A systems.

In order to demonstrate the compliance of a new system, it is first necessary to calculate the amount of degradation to the protected systems' representatives caused by crosstalk from the new system. Next, by comparing the reference performance with the calculated performance taking into account crosstalk, one finds the minimum loop length where the calculated performance is below the reference. In this case the new system is classified into Class C, which in turn can be deployed up to that length. On the other hand, if no crossover point is found whatsoever at distances up to 5km, the new system is regarded as Class B, which has spectral compatibility without any deployment restrictions.

An example is depicted in Fig. 4. The thin line indicates the reference performance downstream (a) and upstream (b) of G.992.1 Annex C DBM (FDM). The dashed line represents the calculated performance taking into account crosstalk from some new system. In this case, the system has the spectral compatibility of Class C with a deployment restriction of 3.5km.

All systems whose compatibility is approved of are put on the Spectral Compatibility Report list [5] available at the TTC website.

TABLE III. REFERENCE PERFORMANCES OF CLASS A SYSTEMS.

Normalized loop length (km)	TCM-ISDN		G.992.1 AnnexA (FDM)		G.992.2 AnnexA (FDM)		G.992.1 AnnexC DBM (FDM)		G.992.2 AnnexC DBM (FDM)	
	DS	US	DS	US	DS	US	DS	US	DS	US
0.50	144	144	7104	832	3008	832	7104	832	3008	832
0.75	144	144	6784	832	2912	832	6880	832	2944	832
1.00	144	144	5856	832	2624	832	6304	832	2752	832
1.25	144	144	4768	800	2240	800	5632	800	2496	800
1.50	144	144	3648	768	1792	768	4928	800	2240	800
1.75	144	144	2400	736	1408	736	4128	768	2016	768
2.00	144	144	1600	704	896	704	3648	736	1696	736
2.25	144	144	1024	640	608	640	3264	704	1504	704
2.50	144	144	672	576	320	576	2976	672	1312	672
2.75	144	144	448	512	160	512	2624	608	1216	608
3.00	144	144	320	448	96	448	2304	576	1152	576
3.25	144	0	192	352	64	352	1888	512	1152	512
3.50	0	0	128	288	32	288	1536	480	1120	480
3.75	0	0	64	224	32	224	1248	448	1056	448
4.00	0	0	32	192	0	192	1056	416	992	416
4.25	0	0	0	160	0	160	864	416	896	416
4.50	0	0	0	128	0	128	736	384	800	384
4.75	0	0	0	96	0	96	576	352	672	352
5.00	0	0	0	64	0	64	352	352	480	352

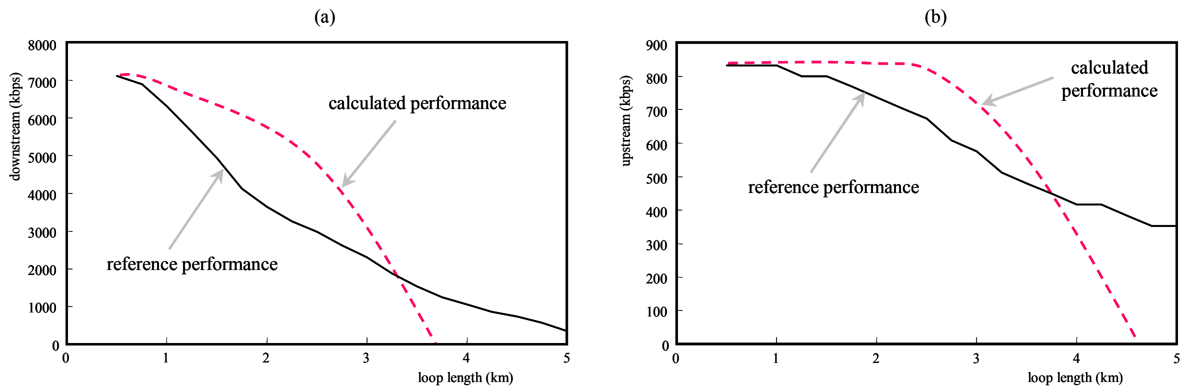


Figure 4. Spectral compatibility process of a new system by comparing with the reference performance of G.992.1 Annex C DBM (FDM). Fig. 4 (a) and (b) indicate performance of downstream and upstream respectively.

IV. TOWARD FURTHER DEVELOPMENT OF DSL SERVICES

As described above, due to the growth in consumer demand for faster Internet access, ISPs have had to upgrade their products. In the case of DSL technologies, a higher bit rate is usually achieved by extending the bandwidth.

Fig. 5 illustrates the history of the transition in shape of PSD in DSL technologies. Early models of DSL transmitted signals over separate frequencies for upstream and downstream, a method called FDM (frequency division multiplexing), resulting in the name “asymmetric DSL” or ADSL (Fig. 5a). At the time, increased downstream bandwidth was called for, primarily because downloading needs exceeded uploading needs, so an overlapped system was developed which overlapped the downstream onto the frequency for the upstream (Fig. 5b). Furthermore, double spectrum was launched, which extends downstream bandwidth to a much higher frequency (Fig. 5c). This almost doubled the transmission speed on the downstream side and contributed to the rapid development of the DSL market. This was the state of affairs at the time of JJ-100.01 Issue 2.

After that, as VoIP and online gaming gained popularity, the next step was the extension of upstream bandwidth. In spite of having over 40 Mbps for transmission speed downstream, upstream at the time remained a mere 1 Mbps. Then, an “extended upstream” system was developed which in turn overlaps and extends bandwidth for the upstream direction to the downstream frequency (Fig. 5d). In addition, some providers are deploying VDSL systems into the Japanese market. As a result, there is a mixture of various systems with different PSDs in the market.

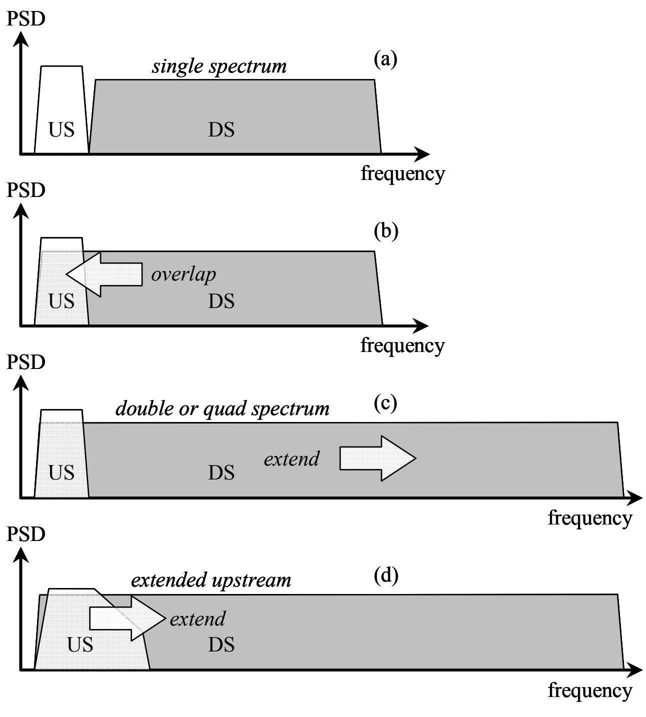


Figure 5. Historical transition in PSD with developments in DSL technology . (a) single spectrum, (b) overlapped system, (c) double or quad spectrum, (d) extended upstream system.

Crosstalk from DSL systems having different PSDs may cause significant interference in their performance. Thus, the following three points became major issues during the creation of JJ-100.01 Issue 3.

A. Extended Upstream Problem

An extended upstream system can have an impact on the transmission performance in downstream direction of existing ADSLs because of differences in PSD. This can be clearly shown by computer-simulated calculations.

On the other hand, one of the unique features of spectrum management in Japan is existence of TCM-ISDN. The largest source of disturbance for general ADSL systems is TCM-ISDN. TCM-ISDN is a protected system because it was in use before DSL services were launched. The reference performance shown in Table 3 already includes degradation by crosstalk from the system. As a result, interference by the extended upstream systems would have created a problem, but not one as considerable as TCM-ISDN. However, because extended upstream systems were set to become staple commodities for companies, there was big concern that the spectral environment might be polluted due to over- deployment.

For this reason, it was the opinion of some that the extended upstream systems should be regulated more strictly than under the emerging standard. In response to this, providers who wanted to launch extended upstream insisted that it was unfair to make another standard to regulate only extended upstream systems, which would, they argued, prevent further technological development. Unless improvements were made in upstream transmission speed, the emerging FTTH would dominate the market.

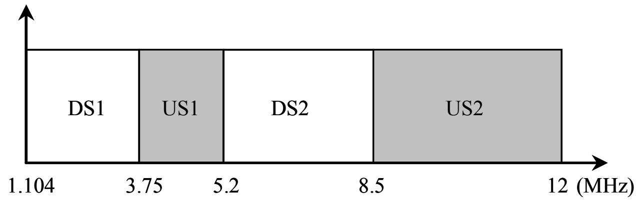
The controversy continued and the passage of over one year did not produce a resolution. Eventually, the idea of the creation of special criteria for extended upstream was abandoned. Now in Japan, the flagship ADSL service is 50 Mbps downstream and 3 Mbps upstream.

B. Spectral Compatibility beyond 1.104 MHz

Until JJ-100.01 Issue 2, the spectral compatibility process applied to frequencies below 1.104 MHz, which equals the bandwidth of a single spectrum. There was at the time no rule in force for spectral compatibility beyond 1.104 MHz. The creation of criteria became an urgent matter due to the advent of double and quad spectrum as well as VDSL.

In Issue 3, an agreement was reached for frequencies beyond 1.104 MHz: a bandplan would be provided so that there would be no more conflict between downstream and upstream caused by various PSDs. Fig. 6 summarizes the bandplan agreed upon in Issue 3, which is equivalent to G.993.1 Bandplan A of ITU-T VDSL standard. Currently, the bandplan provides for up to 12 MHz.

In addition, in terms of power spectral shape, a PSD corresponding to ANSI T1.424 FTTEx Mask2 is now allowable. Its upstream and downstream PSD is illustrated in Fig. 7. A system can be deployed if it satisfies these PSD criteria. On the other hand, all other PSDs must be discussed individually at the Spectrum Management SWG of the TTC.



frequency [MHz]	downstream / upstream
1.104 – 3.75	downstream (DS1)
3.75 – 5.2	upstream (US1)
5.2 – 8.5	downstream (DS2)
8.5 – 12	upstream (US2)

Figure 6. Bandplan applied to frequency beyond 1.104 MHz.

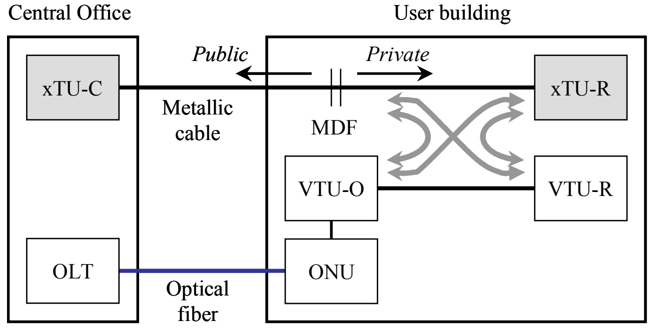


Figure 8. Interference scenario between CO-based xDSL and VDSL deployed in user building.

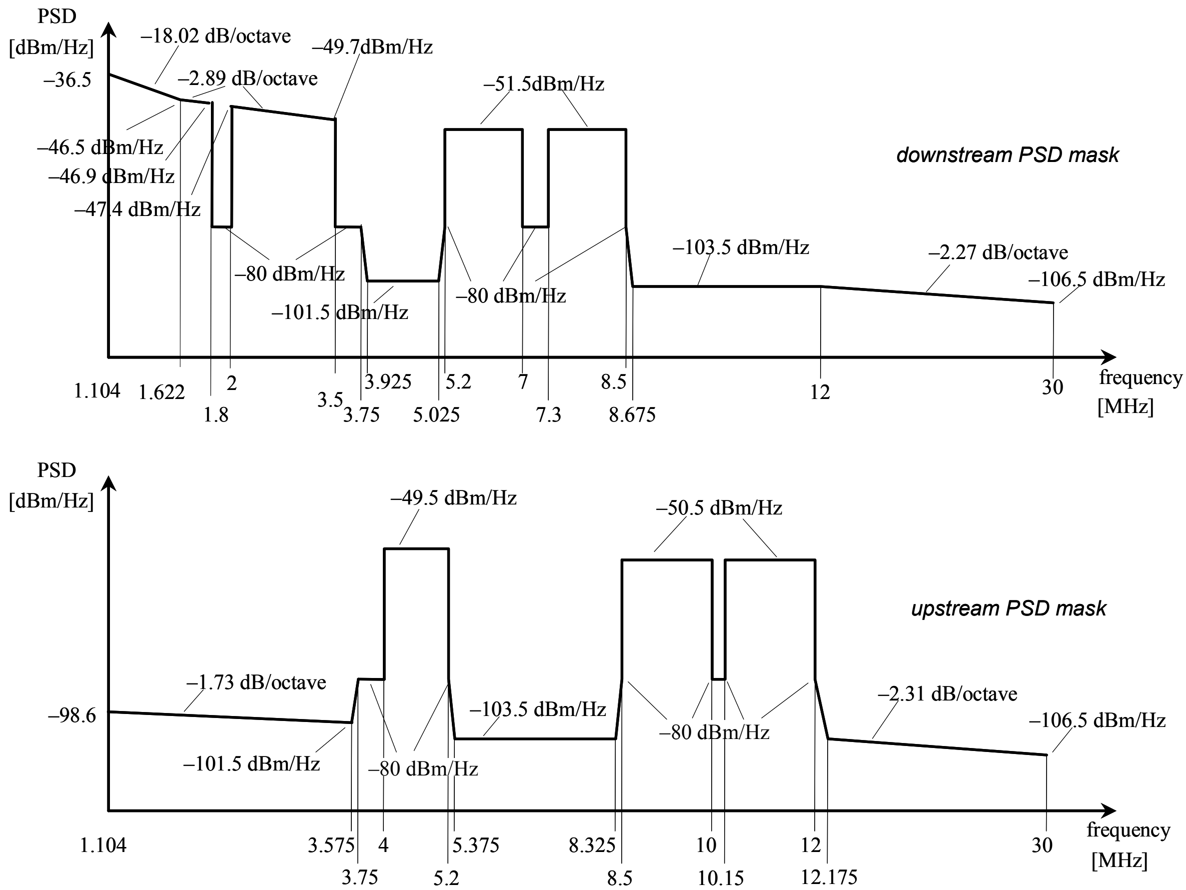


Figure 7. Allowable PSD mask for transmission system using frequency beyond 1.104MHz. (a) downstream and (b) upstream respectively.

C. Technical Guidelines for Alleviating Interference between CO-based xDSL and VDSL deployed in User Buildings

Various operational situations need to be considered as diversification in business models progresses. For example, an increase in the deployment of VDSL could cause the problem of interference between CO-based ADSL/VDSL and VDSL deployed in a user building. This may not be a likely scenario, but if it were to happen, VDSL deployed in a user building would generate FEXT into CO-based xDSL, which is almost as powerful as NEXT.

JJ-100.01 Issue 3 provides a technical guideline to alleviate interference between CO-based ADSL/VDSL and VDSL deployed in user buildings. This is only information for reference, because a user building is not any public loop plant, and is beyond the scope of the TTC.

V. CONCLUDING REMARKS

In this paper, the current state of the broadband market and spectrum management in Japan is described.

Interests often conflict among competitive providers, so it is sometimes difficult to reach an agreement for making a standard. In some cases, a compromise or a trade-off may be necessitated. In addition, since each country has its own unique circumstances, spectrum management would be equally varied. However, what we have in common is that competition between competitive providers will eventually be to the user's benefit. It is important to create an environment to allow competition to progress in an orderly fashion with a spectrum management standard.

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