Feature

Internationalization of the Japanese Digital Terrestrial Television Broadcasting System, ISDB-T

From development of the transmission system to its adoption in Brazil

On June 29, 2006, the Brazilian government announced that it had chosen to use a digital terrestrial television broadcasting system based on Japanese Integrated Services Digital Broadcasting - Terrestrial (ISDB-T). This is the first time that the ISDB-T system had been chosen for Digital Terrestrial Television outside of Japan. The Brazilian government cited several reasons for choosing ISDB-T, including technical superiority, system flexibility, and promotional activities. This paper describes the development and standardization of ISDB-T in Japan and in ITU-R, as well as activities to promote the system internationally. We had thought that a multipath-proof technique would be necessary, from experience with terrestrial digital transmissions such as TELETEXT and FM multiplex broadcasting. Hence, we began studying orthogonal frequency division multiplex (OFDM) at the end of 1980's. This effort led to BST-OFDM (Band Segmented Transmission - OFDM), which is a major feature of ISDB-T. Since 1997, NHK Labs. and DTV-Lab. Co. had been studying a transmission system for digital terrestrial television broadcasting (DTTB). We jointly proposed the transmission system as a DTTB system to ARIB. The system was approved as the Japanese DTTB system in May, 1999. NHK Labs has also been working on setting international standards in ITU-R. Since 1992, we have contributed documents for DTTB to ITU-R. ISDB-T was approved as an ITU-R recommended system for DTTB in 2000. The Digital Broadcasting Experts Group (DiBEG) was established in 1997 as an organization for international promotion of ISDB-T. Japan and Brazil have deepened their relationship over the course of time, Brazil carried out tests comparing three different DTTB systems in 2000, and they fairly evaluated the systems. Brazil recognized technical excellence and system flexibility of ISDB-T, and it eventually adopted an ISDB-T based system as its DTTB standard.

1. Introduction

On June 29, 2006, the government of Brazil announced that it would adopt a system based on the Japanese system, ISDB-T, as the country's digital terrestrial television broadcasting system. This was the first time the Japanese system was used as the basis for a system outside of Japan. Brazil planned to begin digital terrestrial broadcasting in December of 2007 and is currently introducing the latest technology and proceeding with preparations.

There are three international standards for digital terrestrial broadcasting system: ATSC proposed by the USA, DVB-T in Europe, and ISDB-T in Japan; and there was fierce competition among the three leading up to Brazil's decision. There are various possible reasons that the Japanese system was chosen, but the most important were probably the technical advantages and promotional efforts.

In this article we will look back over the domestic development of this digital terrestrial broadcasting system in Japan, its internationalization and promotional efforts overseas, its expansion to over 32.3 million installed receivers (as of Feb., 2008), and its steady progress toward the goal of complete digitalization of Japanese television in 2011.

2. Development of the ISDB-T system

2.1 TELETEXT and FM multiplexing broadcasting

NHK Science and Technical Research Laboratories (NHK STRL) carried out research and development from the 1970's into the mid-1980's on how to multiplex text with television broadcasts so that analog television could be viewed with subtitles. These systems were forerunners to digital broadcasting, with text information sent as digital 0's and 1's. At this time, researchers noticed that although the digital signal was robust with respect to noise, it was weak with respect to certain types of distortion such as ghost interference.

Then, from the mid-1980's, they began researching transmission system, called FM multiplexing broadcasting, which sent text, graphics and traffic

information by multiplexing a digital signal over the FM-radio stereo base-band signal. This resulted in the broadcast system that is currently used for traffic information system (VICS) in car-navigation products. Over half of all FM radios were portable or in automobiles, and these mobile radios naturally needed to be capable of receiving the FM multiplexing broadcasting. However, mobile-receiver antennas have low antenna gain compared with fixed home receivers, and other issues including significant fading distortion made it very difficult for them to receive the multiplexed signal.

Both TELETEXT and FM multiplexing broadcasting use transmission techniques which multiplex a digital signal over an analog broadcast signal, and the development of ISDB-T was built on the experience of developing these technologies.

2.2 Integrated Services Digital Broadcasting (ISDB) Proposal

STRL published a document outlining the Integrated Services Digital Broadcasting (ISDB) concept as a vision for digital broadcasting from the 80's forward. ISDB provides high quality, performance, flexibility and extensibility in a broadcasting service by transmitting video, sound and other data as a digital signal in a unified format. It also attempts to create a common service across different media, whether satellite, cable or terrestrial transmission.

In the 1990's, new, high-performance encoding technologies for video and sound were being developed around the world created new possibilities. What began as an attempt to add new functionality by multiplexing a digital signal with a predominantly video and sound analog signal grew into genuine ISDB research: broadcasting a fully-digital, integrated signal.

Since the development of TELETEXT broadcasting, designs for data communications had become standardized based on the seven-layer Open Systems Interconnection (OSI) model established by the International Standards Organization (ISO). Following this trend, research progressed toward the unification of standards common across all media, such as encoding methods, and standardizing characteristics that differ across transport media, such as the physical layer, on a per-medium basis.

2.3 The beginning of digital terrestrial broadcasting research

Research of a digital terrestrial broadcasting system at STRL began in the latter half of the 80's. In contrast to satellite or cable transmission, digital terrestrial signals are affected by various types of distortion, including multi-path distortion due to reflections from buildings and geographical features, impulse noise from automobiles, and fading distortion from fluctuations in the received signal level. Even though digital broadcasting is robust with respect to noise, the experience gained in research and development of TELETEXT and FM multiplexing broadcasting made it clear that new technology tolerant to these types of distortion would be needed for digital terrestrial broadcasting. OFDM research began as one possible such technology.

The principles of OFDM had been known since the 1960's, but it had not yet been implemented practically.

Prompted by the use of OFDM for Digital Audio Broadcasting (DAB) in Europe in the 1980's, STRL began real research into OFDM. Although OFDM is susceptible to non-linear distortion, it is robust against multi-path distortion, and because the modulation method allows relay broadcasting on the same frequency, it also contributes to efficient use of bandwidth. Furthermore, when combined with time interleaving, it is excellent for portable and mobile reception, making it an excellent modulation technique overall.

So, computational simulations were begun in the late 1980's, prototype specifications were written starting in 1990, and development of prototype OFDM devices began. A prototype DQPSK-OFDM device was built first (Figure 1), followed by multi-level OFDM prototypes including 16QAM-OFDM and 64QAM-OFDM, as the rounds of testing progressed.

Research into multi-level OFDM, like 64QAM, was needed for transmission of High Definition TV programs in the 6 MHz band. Also at the time, related experiments

Figure 1: The first OFDM Modem for digital terrestrial broadcasting in Japan (1992)

Figure 2: Early mobile reception experiments (1993)

on clock regeneration, frequency synchronization, frame synchronization, interference with analog broadcasts and Single Frequency Network (SFN) were done to determine the most promising transmission method.

Then, in 1993, STRL received the first license for an experimental station using OFDM modulator in Japan, installed a transmitting antenna on the STRL roof and began open-air field test with fixed and mobile receivers (Figure 2).

2.4 BST-OFDM Research

Analog terrestrial broadcasting in Japan is a general, national service which uses about 15,000 channels, including NHK and commercial stations. This results in channel congestion that is unprecedented in the world and conditions that make it extremely difficult to initiate digital broadcasting using the same frequency bands as analog television broadcasting. The BST-OFDM modulation method was conceived to address this problem (Figure 3). This technology broadcasts a wide-band signal by splitting it into several narrower bands for transmission. However, new technology soon made it possible to change the channel of an analog broadcast (analog-to-analog conversion) and thus secure the bandwidth needed for digital terrestrial broadcasting, so the need to split up the digital signal for transmission diminished. Instead, a modulation method was adopted with a digital signal transmitted in the 6 MHz band, dividing the signal into several segments, and allowing the modulation method to be configured separately for each segment. This resulted in ISDB-T, the current digital terrestrial broadcasting format. Note that BST was originally an abbreviation for Band Split Transmission, but this name was later changed to Band Segmented Transmission.

2.5 Collaborative research with DTV-Lab

In 1995, a time-limited company called the "Next-

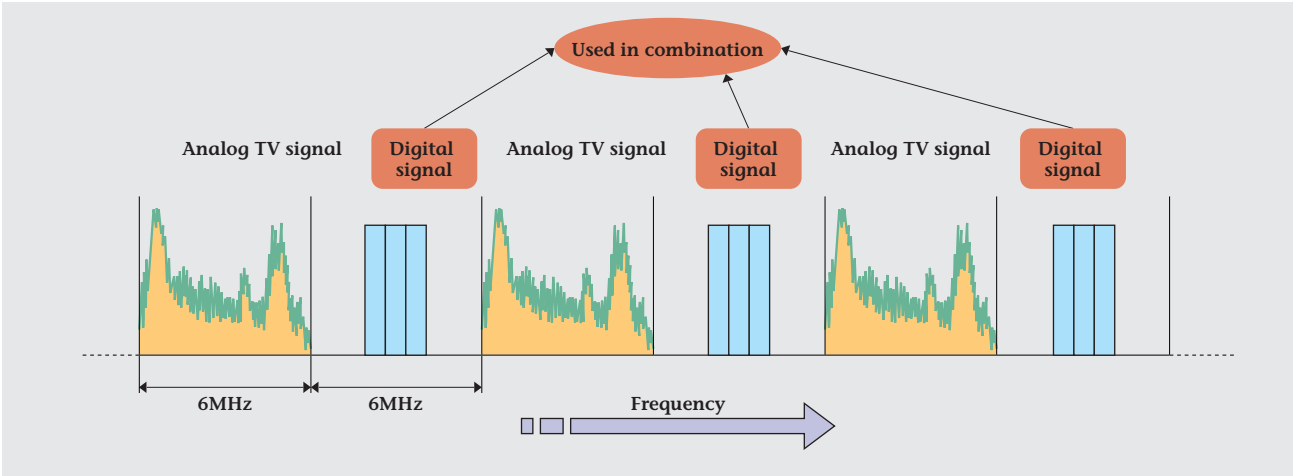

Figure 3: Initial BST-OFDM concept

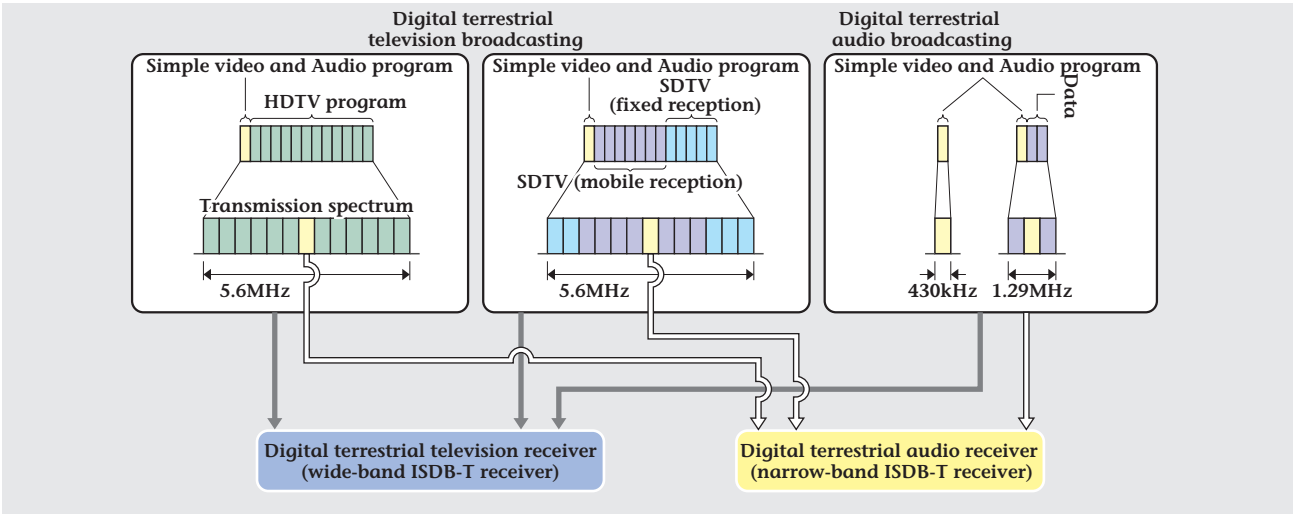

Figure 4: ISDB-T Transmission diagram

generation digital television broadcasting system laboratory Inc." (DTV-Lab) was established to accelerate the study of digital broadcasting transmission methods. STRL engaged in collaborative research with DTV-Lab from 1997 to advance the study of digital terrestrial broadcasting system for Japan. The current digital terrestrial broadcasting transmission method in Japan is the result of this collaborative research between the NHK STRL and DTV-Lab, which finalized various elements of the ISDB-T transmission method.

2.6 ISDB-T Features

To develop the digital terrestrial broadcasting method, the broadcasting system requirements were first decided, and then a method was developed to conform to these requirements. The main features of ISDB-T are described here. Figure 4 gives a conceptual representation of ISDB-T transmission.

(1) Supports HDTV Services
(2) Supports multi-channel SDTV services
(3) Supports data transmission
(4) Supports mobile and portable reception
(5) Contributes to efficient use of frequency, supports SFN
(6) Encoding and multiplexing methods are compatible with Broadcast Satellite (BS) digital broadcasting and use international standards
(7) Considers compatibility with digital terrestrial audio broadcasting
(8) Divides the 6-MHz band signal into 13 segments
(9) Supports per-segment configuration of modulation parameters and hierarchical transmission up to three layers.

At first, the central segment, segment one, was allocated to allow partial reception of only the audio signal, but later with the advancement of video compression technology, it became possible to use it for the current One-Seg service.

3. Domestic and international standardization activity

3.1 Domestic standardization activity

To standardize a new transmission method in Japan, first an inquiry into the technical requirements is done by the Telecommunications Council (TC), which is an advisory body of the Ministry of Internal Affairs and Communications. Then, once the report on technical requirements has been completed and before the new standard is finally established, the Radio regulatory council conducts an inquiry and report into amendments to ministerial orders for related technology standards. In most cases, most of this practical work related to technical requirements is carried out by the private organization, the Association of Radio Industries and Businesses (ARIB). The particulars of the standardization of digital terrestrial broadcasting in Japan are summarized in Table 1.

In June, 1994, the Telecommunication Technology Council (TTC), which was an advisory body of the Ministry of Posts and Telecommunications at the time, established the Digital Transmission System Committee based on their inquiry No. 74, "Technical requirements for digital broadcasting systems". The second working group (WG2) under this committee conducted deliberations on digital terrestrial broadcasting method. In September, 1996, the digital terrestrial broadcasting system development section was established in ARIB, and concrete deliberations began.

STRL and DTV-Lab submitted a proposal in collaboration with ARIB for a digital terrestrial broadcasting transmission method resulting from their joint research. ARIB and the TTC deliberations then proceeded based on this proposed method. In September, 1997, the TTC settled on a tentative draft for the transmission portion of the digital terrestrial television broadcasting system. Prototype hardware was built based on this tentative draft, and laboratory experiments and

Table 1: Particulars for standardization of digital terrestrial television broadcasting in Japan

Date	Description
June 1994	Inquiry No. 74, "Technical requirements for digital broadcasting systems"
Sept. 1996	ARIB Digital Terrestrial Broadcasting System Development Section established
June 1997	NHK STRL and DTV-Lab jointly propose experimental system specifications to ARIB
Sept. 1997	TTC settles on a tentative draft for the transmission portion of the digital terrestrial television broadcasting system
July/Aug. 1998	ARIB conducts basic open-air transmission tests using prototype equipment based on the draft proposal
Sept. 1998	TTC settles on tentative system for digital terrestrial television broadcasting
Approx. 3 mo. from Oct. 1998	ARIB conducts large-scale test using prototype equipment based on the tentative standard
May 1999	TTC "Digital Terrestrial Television Broadcasting System technical requirements" report
Nov. 1999	Radio regulatory council approves "Amendments to related ordinances required to finalize the technical standards and adopt the digital terrestrial Television broadcasting system"

basic-transmission open-air experiments were conducted, mainly by ARIB. A tentative digital terrestrial television broadcasting system was settled a year later in September, 1998, based on the results of these experiments.

Large-scale test was then done based on this tentative standard, with test stations in the Tokyo Tower and other locations; taking measurements including fixed and mobile reception and SFN characteristics to verify the performance of the system.

In May, 1999, the "Digital Terrestrial Television Broadcasting System Technical Requirements" report from the TTC was accepted by the Ministry of Posts and Telecommunications.

In September, 1999, the Ministry of Posts and Telecommunications submitted amendments to related ordinances to the Radio Regulatory Council, as required to finalize the technical standards and adopt the digital terrestrial broadcasting system, and in November, 1999, they received partial approval for the draft from the council.

Through ARIB, STRL actively contributed to investigation of the format, laboratory and open-air basic tests, SFN test, and large-scale test for the digital terrestrial broadcasting system.

3.2 International Standardization Activities

International standards dealing with radio frequencies in the telecommunications field come in the form of reports from the International Telecommunication Union (ITU). In order to have the Japanese digital terrestrial broadcasting system classified as an international standard, it needed to be accepted and recognized as an ITU recommendation, so from the beginning of development, NHK actively contributed to ITU standardization activities for the system. We describe the process leading to acceptance of the Japanese digital terrestrial broadcasting system as an ITU recommendation below. An overview of this process is shown in Table 2.

At the time, deliberation on recommendations for digital terrestrial television broadcasting were carried out by the Study Group 11 (SG11) of the radio-communication sector (ITU-R) of the ITU, which presided over all television-broadcasting-related matters. The new research topic, Question ITU-R 31/6 (formerly 121/11) "Digital terrestrial television broadcasting", describing multiplexing, error-correction, modulation and other methods applicable to digital terrestrial television broadcasting was approved in 1992. In January, 1992, task group TG 11/3 under SG11 was established to deliberate on recommendations related to the new research topic. Then, at a meeting in November, 1996, in Sydney, TG 11/3 completed the final several draft recommendations related to digital terrestrial television broadcasting.

The International standard recommendation for digital terrestrial television broadcasting, BT.1306 ("Error-correction, data framing, modulation and emission methods for digital terrestrial television broadcasting") was adopted in October, 1997, at the ITU-R wireless communications general meeting (RA97). Within this recommendation, it was recommended that one of two methods, ATSC (USA) or DVB-T (Europe) be used, and descriptions of their respective error correction, framing, modulation, and emission methods were given in Annex 1. The Japanese proposal, ISDB-T, was described in Annex 2 as still-under-development and not yet accepted in its domestic market.

Since being established in 1992, TG 11/3 contributed various documents towards NHK's eventual adoption of the standard in the future. TG 11/3 was disbanded in November, 1996, and deliberations on digital terrestrial television broadcasting moved to WP11A, a working section of SG11. We continued submitting information on the development status and test results for the Japanese system, ISDB-T, even after the broadcast recommendation BT.1306 was adopted, and in May, 1999, the ISDB-T system was accepted domestically. Japan then proposed to the ITU-R that the ISDB-T system be added to the international recommendation.

Proposed revision to the BT.1306 recommendation was

Table 2: ITU-R Deliberations on digital terrestrial broadcasting

Date	Description
Jan. 1992	New research topic (Question ITU-R 31/6) on "Digital terrestrial television broadcasting" approved Task group TG 11/3 established under SG 11 to deliberate on this topic
Nov. 1996	Task group TG 11/3 disbanded
Oct. 1997	Digital terrestrial television broadcasting recommendation, BT.1306, "Error-correction, data framing, modulation and emission methods for digital terrestrial television broadcasting" approved (recommending only the European and American system)
Oct. 2000	Digital terrestrial television broadcasting recommendation, BT.1306, amendments approved (adding Japanese system)

accepted at the general meeting of SG11 in February, 2000, adding the ISDB-T system to the already-accepted ATSC and DVB-T systems. Then a poll was conducted through the mail by the supervisory board, and finally, in October 2000, the revised recommendation was officially adopted.

Note that the proactive effort by the ITU-R towards standardization of ISDB-T was one of the reasons Brazil became aware of the system and lead to the correspondence that followed.

4. Overseas promotional activities

4.1 DiBEG

In September, 1997, when most of the transmission portion of ISDB-T had taken shape, the Digital Broadcasting Experts Group (DiBEG) was inaugurated to promote its adoption overseas in parallel with efforts to gain recommendation status with the ITU-R. The specific objective of DiBEG was to promote adoption of ISDB-T internationally, and initially it focused efforts on giving seminars and demonstrations to various countries in Asia that had not yet decided on a digital terrestrial television broadcasting system. This effort only later came to focus Brazil.

DiBEG originally began as a private organization and a liaison group for international collaborative research in digital broadcasting technology, but was later re-formed as a section under the ARIB promotional committee for the international promotion of digital broadcasting technology. NHK has collaborated with the international promotion of ISDB-T through DiBEG. Table 3 summarizes the major DiBEG activities, including its collaboration with NHK.

4.2 Early activities of DiBEG

One of the early activities of DiBEG was to promote ISDB-T by attending the International Broadcasting Equipment Exhibition, InterBEE, in 1997 and 1998, exhibiting prototype equipment to visiting technologists from the various Asian countries, and explaining the principles and characteristics of the ISDB-T system.

They also conducted demonstrations and equipment loans overseas, including participation in experiments comparing the three major systems in Singapore in 1998 and Hong Kong in 1999. However, even though the ISDB-

Table 3: Major DiBEG Activities

Date	Description
Sept. 1997	DiBEG Established (private organization)
Nov. 1997	Demonstration exhibit at the InterBEE 1997 International Broadcasting Equipment Exhibition
Aug./Sept. 1998	Laboratory and field test in Singapore
May/June 1999	Laboratory and field test in Hong Kong
Jan.-Mar. 2000	Tests comparing the three systems in Brazil
Apr. 2000	ABERT/SET holds debate with representatives of the three systems
Aug. 2000	Seminar and demonstration of fixed, mobile and One-Seg reception of ISDB-T at SET2000
Aug. 2001	Lecture on the advantages of ISDB-T at SET2001
Mar. 2002	Re-launch of DiBEG (under the ARIB organization)
July 2002	Japan's DTTB schedule and new technology introduction at SET2002
Sept. 2003	Introduction to Japanese digital broadcasting, NHK STRL new research and broadcast antennas at SET2003
Nov. 2003	Development of original Brazilian system announced, SBTVD study group established to work on it
Jan.-May 2004	Tests comparing three systems re-done in Brazil
Aug. 2004	Introduction of the state of the technology in Japan, digital devices and demonstration of mobile receivers at SET2004
Mar. 2005	Seminar for CPqD in Brazil
Apr. 2005	Brazil communications ministry announces a decision on system will be made Feb. 2006
Sept. 2005	Introduction of NHK STRL new research, technology status in Japan and new receiver equipment at SET2005
Nov. 2005	A representative group from Japan meets with major agencies, organizations and companies in Brazil to promote adoption of the Japanese system
Jan. 2006	Presentation of the advantages of the Japanese system to ministers of various Brazilian ministries
Apr. 2006	Demonstration of ISDB-T and One-Seg receivers to Brazilian broadcasters and equipment vendors
Apr. 13, 2006	Memorandum signed between foreign affairs ministers of Japan and Brazil
June 29, 2006	Brazil officially adopts a system based on ISDB-T

Figure 5: Laboratory experiments at Mackenzie University

Figure 6: Open air mobile reception experiments in San Paulo

T system produced the best results in these experiments, the format was not chosen for other, non-technical reasons and because real broadcasting in the system had not yet begun (Japan had not yet begun digital broadcasting by ISDB-T domestically).

4.3 Activities promoting the format in Brazil

In 1998, the CTO, F. Bittencourt, of the largest television station in South America, TV Globo, requested Osamu Yamada, ex- director general of STRL, to give an introductory presentation of ISDB-T at the Brazil Television Association Conference (SET1998). This was the first contact with Brazil regarding ISDB-T. Thereafter, Brazil asked to borrow ISDB-T equipments so that they could conduct fair technical evaluations and select the system that really was the best, so DiBEG participated in experiments comparing the three major systems in Brazil.

Laboratory and field tests were carried out in Sao Paolo from January to March in 2000 (see Figures 5 and 6). This was the first time that the three systems had been tested under the same conditions. Brazil published the results of these tests, making it clear that ISDB-T yielded the best results of the three (see Figures 7 and 8). A major reason that ISDB-T proved the best was that it uses time interleaving. In addition to the performance of ISDB-T, Brazil also focused on the flexibility of the system. The

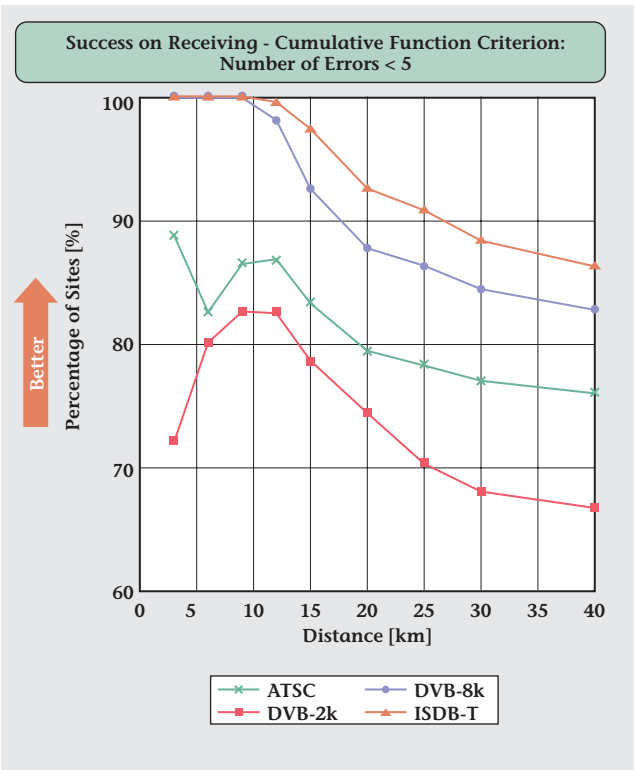

Figure 7: Comparison of correct reception rates in field experiments

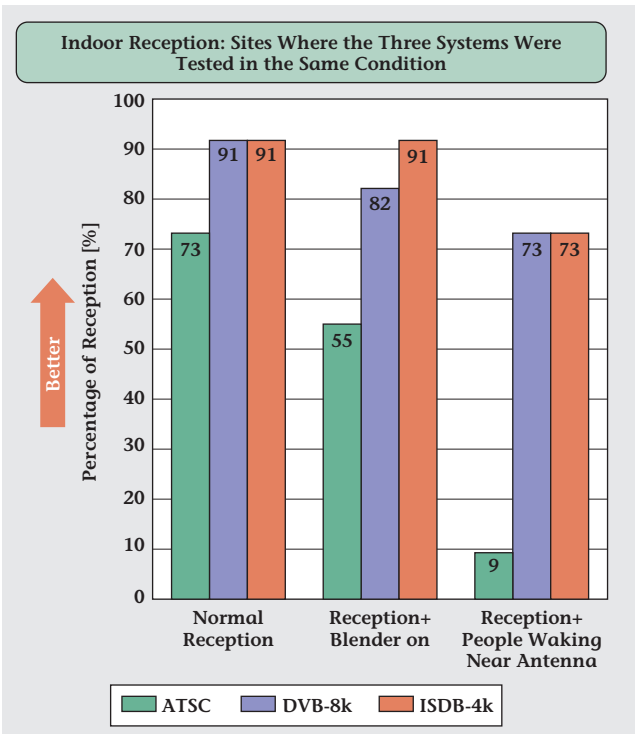

Figure 8: Results of experiments with indoor antenna reception
Note: Figures 7 and 8 are from seminar materials of a seminar comparing the three systems, sponsored by Brazil and co-sponsored by NAB2000 in the United States

Figure 9: Indoor Demonstration in Buenos Aires

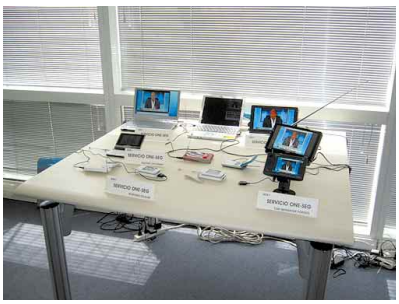

Figure 10: One-Seg Demo in Buenos Aires

ability to reorganize the system according to regional characteristics or changes in the business model of the broadcaster, features like HDTV, multi-channel, vehicle-oriented mobile reception, and services for "One-Seg" phones was evaluated highly. These features were made possible through the segmented architecture, hierarchical transmission, MPEG2 multiplexing and other technical features of ISDB-T. In spite of Brazil's good evaluation of ISDB-T, the biggest obstacle to adopting the system was the fact that Japan did not commence broadcasting in ISDB-T until 2003.

After that, there was a change of political power in Brazil, resulting in policy changes toward developing their own system. Even in those conditions, DiBEG continued its efforts, with presentations and demonstrations focusing on Brazil and South America. TV Globo and the major television broadcasters also continued their support of ISDB-T.

Then, when Communications Minister Costa (formerly of TV Globo) assumed the post of Third Communications Minister in the President Lula administration in July, 2005, suddenly major developments began to emerge. Development of Brazil's own system, which was not making progress, was abandoned, and it was announced that a system would be selected by February 10, 2006. They held hearings to discuss various aspects including technical strengths, equipment costs, and technical collaboration. From November, 2005 till April, 2006, a group representing Japan visited Brazil three times to attend negotiations. Then, on April 13, 2006, the Japanese government and the Federal Republic of Brazil signed a memorandum that Brazil would implement ISDB-T as the base digital television system, and for cooperation with the development of Brazil's electrical and electronic industries related to this decision. Then, on June 29, 2006, government guidelines for implementing the content of this memorandum were signed in Brasilia, finally bringing the efforts of DiBEG to fruition after seven years since the first contact with Brazil.

While STRL was collaborating with DiBEG, it also worked to build the trust-relationship with Brazil, supporting their thorough understanding of ISDB-T transmission technology by accepting three technicians from Brazil TV Globo in 2002 and a professor from Mackenzie University in Sao Paolo in 2005 as visiting researchers.

Note that the Brazil system is called "ISDB-T based" because additional features were added, such as H.264 video encoding, which is used for HDTV transmission in Brazil.

4.4 Activity promoting ISDB-T throughout South America

Brazil's selection of a system for digital terrestrial broadcasting affected the surrounding South American countries, prompting them to begin deliberation to select their own systems. DiBEG has been actively pursuing the spread of ISDB-T throughout South America, receiving requests for seminars and demonstrations from Argentina, Chile, Venezuela, Colombia, Peru and others. In December, 2006, demonstrations of ISDB-T in indoor and outdoor mobile reception were carried out in Buenos Aires, Argentina. In Buenos Aires, a promotional video called "ISDB-T One signal, unlimited reception" was hastily created, but in spite of this it was exceptionally well received. Then, in February, 2007, the same demonstration as in Argentina was held in Santiago, Chile. The demonstration in Argentina is shown Figures 9 and 10.

5. Conclusion

We have described the development of the ISDB-T digital terrestrial broadcasting system, its standardization, and activity to promote it overseas. These are affected by links with many elements of a country's system-selection process. For Brazil, it took approximately eight years from beginning to end to decide on a system. During that time, DiBEG engaged in various activities in Brazil and NHK accepted visiting researchers to strengthen the relationship and facilitate understanding of ISDB-T.

When efforts to promote ISDB-T overseas began,

broadcasting had still not begun in Japan, and there were no consumer receiver devices available, so ISDB-T was forced to compete at great disadvantage compared to competitors from Europe and America. Then domestic broadcasting began in December, 2003, and the price of receivers dropped suddenly. In April, 2006, the One-Seg service also started, the benefits of the Japanese system started to become more widely known, and though technically superior from the start, only then did it quickly to predominance.

One of the major reasons that Brazil eventually decided on ISDB-T, even though Japan is not generally strong in lobbying activity, was that Brazil understood the excellence, flexibility and practicality of the technology. This is the real fruit of the efforts of all the people in Japan who worked on the development, standardization, implementation and promotion of the ISDB-T system.

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