Development of Satellite and Terrestrial Digital Broadcasting Systems in Japan

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1. Introduction

Due to the remarkable advancement of digital technologies such as video compression techniques, the increased density and processing speed of LSI's, and the development of digital transmission systems, total digital broadcasting systems ranging from program production to receivers are approaching implementation.

Since 1983, NHK have been engaged in research and development work on Integrated Services Digital Broadcasting (ISDB) as a new broadcasting concept with flexibility, expandability, and commonality. The goal has been to develop a digital broadcasting system to provide broadcasting services that fully incorporate the advantages of digital signals and appeal to the viewing audiences, instead of merely replacing the conventional analog broadcasting services with digital signals. This was proposed by Japan in 1985 as a new research subject and was approved as a Question at the ITU-R[1].

Many countries now announce to start digital broadcasting. The United States began multi-channel satellite digital broadcasting in 1994 for the first time in the world. Similar multi-channel digital satellite broadcasting was begun in Europe in 1996, and Asian countries, including Korea, are planning to begin digital broadcasting.

In the field of terrestrial digital broadcasting, the United States is planning to begin services which will include HDTV in May 1999 in ten biggest cities. In Europe, the BBC announced that it will begin terrestrial digital broadcasting in 1998[2].

Concerning digital broadcasting using broadcasting satellites (BS), Japan is going to start digital satellite broadcasting including HDTV by BS-4b to be launched around 2000. Research and development of terrestrial digital broadcasting have been developed aiming at the completion of the system before the year of 2000.

2. Features of Digital Broadcasting

Features of digital signals are:

a. less susceptible to noise than analog signals.
b. enable large compression of video and audio signals.
c. enable error correction techniques, which are not applicable to conventional analog signals.
d. because only "0" and "1" signals are used, the video, audio, data, and control signals are processed in the same manner.
e. can be scrambled easily.
f. generally require less transmission power.
g. channels can be allocated easily.
h. modulation systems robust against ghosts and phasing have been developed.
i. suitable for LSI technology.
j. quality of service reduces rapidly when the receiver leaves the service area.
k. new frequencies for digital broadcasting are required.
l. viewers must purchase new receivers.
m. investments in facilities are required of the broadcasting station.

3. Digital Satellite Television Broadcasting

3.1 Requirements for digital satellite broadcasting in Japan

The following items have been discussed in Telecommunication Technical Council, as the main requirements for a transmission system for digital satellite broadcasting.

a. is able to secure the largest possible transmission capacity within a limited frequency band and assures stable reception at a low CN ratio.
b. can provide high-quality picture and sound, including HDTV.
c. can accommodate future expandability and is flexible.
d. is compatible with other media.
e. can be configured with low-cost receivers

3.2 System selection and technical conditions

CS digital broadcasting in Japan, which began in 1996, uses the QPSK modulation system, is standardized with a

27-MHz band and a symbol rate of 21.1 baud, and has an information transmission capacity of approximately 29 Mbps with the generally-used convolutional codes with a coding ratio of 3/4. Requirements **a.** and **b.** must be met with an information transmission capacity larger than the above; the following three items are suggested measures for achieving this:

a. Using a convolutional coding rate in the CS digital system of 7/8 instead of 3/4.

b. Adopting the Trellis Coded 8PSK(TC8PSK) **[3]**: as the modulation system, TC8PSK which is combined with 8PSK and an convolution error correcting code, instead of the conventional QPSK, to enable transmission of a larger volume of information within a limited bandwidth.

c. Adopting a bandwidth larger than the conventional 27 MHz and with the highest possible transmission symbol rate since digital signals have a better protection ratio from interference than analog signals.

Although **a.** will save the number of bits for error correction codes and can increase the transmission capacity by 1/6, the coding gain by error correction decreases, accompanied by a higher CN ratio on the service margin.

Although **b.** enables a 33% increase in the actual information transmission capacity within the same bandwidth, the CN ratio on the receiving margin is increased by 2 dB and becomes more susceptible to effects from rainfall. Adopting a transmission system with variable modulation could be a method of contending with the attenuation of the radio waves due to rainfall. This would enable the transmission of signals that can secure video and audio information using a time-division system, even if the picture quality decreases, by providing a modulation system that is less susceptible to errors than the TC8PSK. Both the information transmission capacity and reliability during rainfall could be achieved by adopting such a variable modulation system. The relationships between the information transmission volume and the required C/N and the rain attenuation margin of each digital modulation system (TC8PSK, QPSK, BPSK), assuming that the satellite EIRP is the same as that of the current BS-3, are shown in **Fig.1** using the transmission symbol rate as the parameter. The characteristics of the basic specified parameters of each transmission system can be estimated from this figure.

Item **c.** is directly connected to the BS channel plan and cannot be decided independently in Japan; those procedures will be decided by WRC '97. Since the channel separation of CS channels is 30 MHz with a signal bandwidth of 27 MHz and the channel separation between BS channels is approximately 38 MHz, it is possible that the BS signal bandwidth will become 36 MHz or more. In addition, compared with the strict restrictions regarding interference with analog signals, various evaluation tests have confirmed that the digital signal bandwidth can be expanded to 36 MHz without any interference problem, and we know that they can be transmitted with a low transmission loss by a standard design BS satellite.

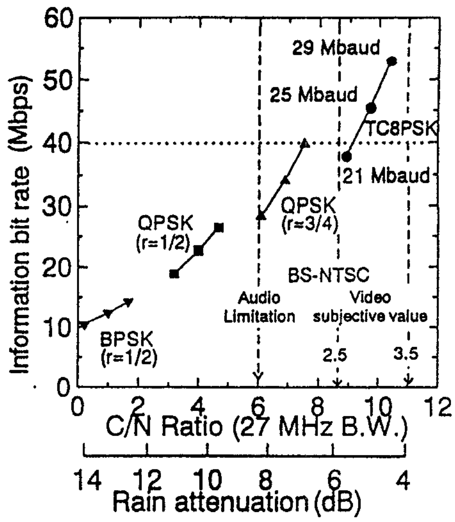

Fig.1 Relationship between modulation methods and information bit rate

3.3 Transmission system for digital satellite broadcasting

Based on the above-mentioned three items, six transmission systems -A to F- can be considered, as shown in **Table 1**.

Digital broadcasting can expand the signal transmission bandwidth since it has a better protection ratio from interference than analog broadcasting. Moreover, digital HDTV broadcasting requires a larger information transmission capacity to broadcast pictures that contain rapid motions, such as sports scenes. Therefore, it is necessary to secure frequency resources in the future which facilitate the widest possible bandwidth , such as system F in **Table 1**.

4. Digital Terrestrial Television Broadcasting

4.1 Requirements for terrestrial digital broadcasting

Deliberations are progressing in the Telecommunications Technology Council, and detailed technical matters are discussed in the Association Radio Industry and businesses(ARIB) concerning terrestrial digital broadcasting in Japan. The following are considered to be the main requirements for the system:

Table 1 Examples of digital satellite broadcasting methods.

	A	B	C	D	E	F
Modulation	QPSK	2/3 TC8PSK				
Error correcting code	RS+Convolution code(7/8)	RS				
Baud rate	21.1M Baud			27*M Baud		29*M Baud
Baud width	27MHz			<33MHz		<36MHz
Transmission control	No	No	TMCC	No	TMCC	TMCC
Information bit rate	34.0Mbps	38.9Mbps	38.9Mbps	49.1Mbps	49.1Mbps	52.8Mbps
CN ratio Limitation High resolution Low resolution	8.1dB -	8.5dB -	8.5dB 3.3dB	9.6dB -	9.6dB 4.3dB	9.9dB 4.7dB

*: Maximum

a. Must provide HDTV services.
b. Alternatively, must provide multichannel standard TV broadcasting.
c. Must enable standard TV mobile reception.
d. Can contribute to the effective use of frequencies.
e. Must consider digital audio broadcasting.

Regarding requirement **c.** , the current TV broadcast can be received at mobile stations although the reception quality is low; in fact, many taxis are installing TV receivers. The Orthogonal Frequency Division Multiplexing(OFDM) modulation method is robust against multipath and fading interference. It should be considered to implement large-capacity mobile multimedia broadcasting services, which utilize the features of VHF and UHF signals.

Requirement **d.** is important because frequencies are scarce and limited and are precious national resources. Japan already uses many frequencies in the VHF and UHF bands with few idle channels. OFDM has functions supporting a Single-Frequency Network (SFN), so it is possible that it will provide services at the same frequency, including repeating stations in local service areas. In that case, many frequencies could be saved.

4.2 Basic tests of the SFN

OFDM, which transmits digital information by distributing it to many orthogonal carriers, is resistant to ghosts and multipath fading. NHK Science and Technical Research Laboratories performed various transmission tests on OFDM signals radiating from an antenna installed on the premise in 1992. Since 1996, the SFN with two stations has been tested using experimental stations consisting of the Laboratories and the NHK broadcasting center, connected by optical fiber. The mobile receiving test of the Metropolitan Highway indicated that the SFN provided almost the same receiving point ratio as the conventional network, which uses different frequencies, and thus the SNF effectiveness was confirmed.

4.3 Transmission systems for digital terrestrial broadcasting

Based on the results of various computer simulations and transmission tests, Band-Segmented Transmission-OFDM (BST-OFDM) was proposed as a terrestrial digital transmission system that meets the requirements in **4.1**, to Japanese Telecommunications Technology Council by ARIB last year, and the field trials are supposed to be carried out by ARIB this year aiming at the final specifications. A sample image of the BST-OFDM transmission of services is shown in **Fig. 2**. This system uses OFDM technology, which enables mobile reception and SFN, to assign different modulation systems to each segment. Through hierarchic transmission, the system enables more flexible configurations, such as HDTV or simultaneous broadcasting of multiple services with different transmission strengths. If the primary service is audio broadcasting, it can be transmitted within a narrow bandwidth of 432 kHz.

4.4 Themes of terrestrial digital broadcasting

There are many issues to be addressed when introducing terrestrial digital broadcasting in Japan. The main issues include:

a. establishing a system that meets the requirements.
b. using the idle channels that are available in each area.
c. examining the introduction strategies.
d. forming a channel plan.
e. clarifying the technical conditions for implementing SFN.
f. developing attractive services.

g. securing a large budget to construct the new broadcast stations and repeaters that this system requires.

5. Conclusions

Digital broadcasting implementation is advancing more rapidly in Europe and America than in Japan. Digital broadcasting research and development in Japan is promoted to convert the current analog broadcasting into digital broadcasting as well as to fully utilize the features of digital broadcasting and further expand the broadcasting system's potential. This expansion will include not only improving the picture quality but also taking a long view of the future and the possibilities for new services and the fusion of broadcasting and communications.

The detail specifications on Japanese satellite and terrestrial broadcasting systems are discussed in the Telecommunications Technology Council and ARIB, aiming at the completion, satellite in 1998, and terrestrial in 1999.

References

[1] ITU-R Question 101-1/11 : "Integrated Services Digital Broadcasting(ISDB) in the Broadcasting Satellite Service"

[2] IIC : "Digital Terrestrial TV", Intermedia Special Report, Vol.25, No.2(1997)

[3] G. Ungerboeck : " Channel Coding with Multi Level/Phase Signals", IEEE Trans. Info. Theory,IT-28,1,pp.55-67(1982)

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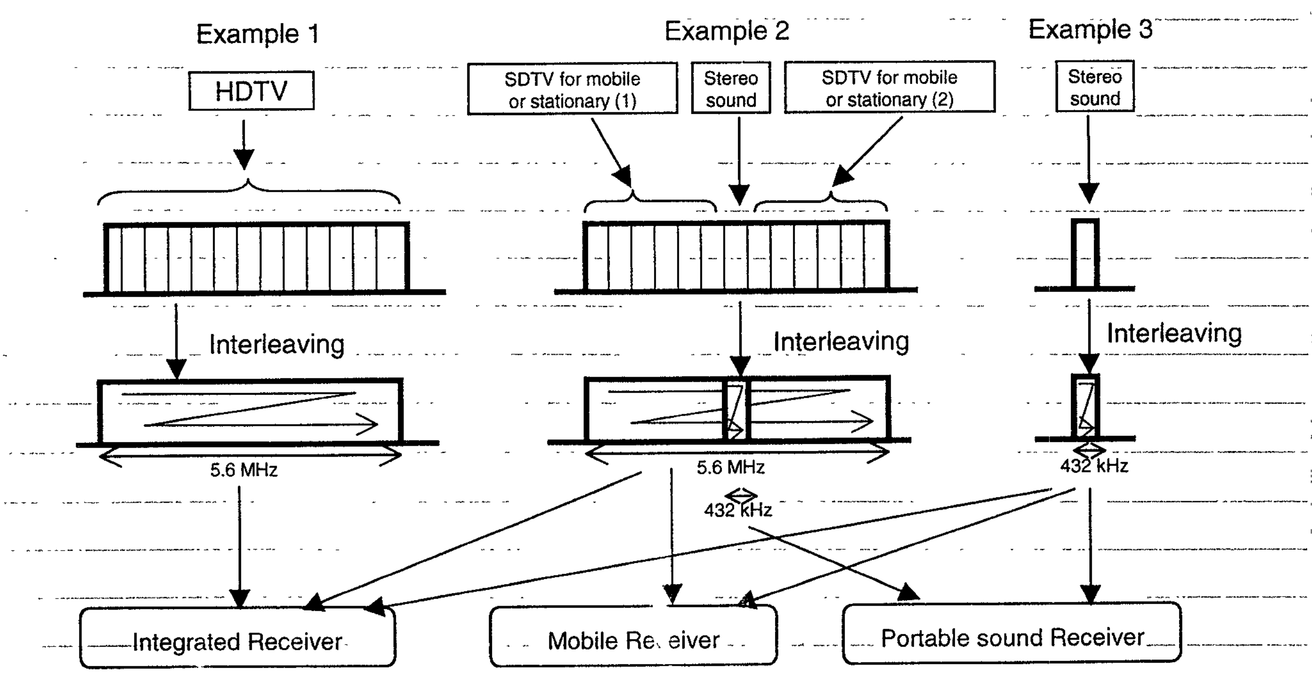

Fig.2 Examples of applications and transmission images of BST-OFDM.