FUJITSU TEN's Approach to Digital Broadcasting

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1. Introduction

There has been a notable increase recently in the number of television commercials advertising television sets that can receive broadcasts in digital format. In a move reminiscent of the shift from the analog record to the compact disc (CD) and the mini disc (MD), the broadcasting industry is gradually moving toward digitization.

This technical note gives an overview of, and introduces the current state of affairs surrounding digital broadcasting worldwide, and Fujitsu TEN's efforts in this field.

2. Understanding Digital Broadcasting

Conventional broadcast systems that transmit signals that are continuous over time through amplitude modulation (AM) or frequency modulation (FM) were once common. In contrast to these analog broadcast systems, digital broadcasting uses a variety of encoding and multiplexing technologies for transmission.

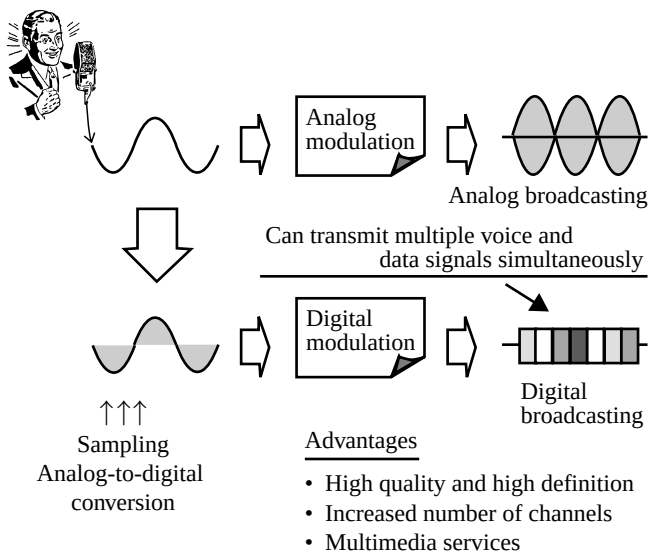
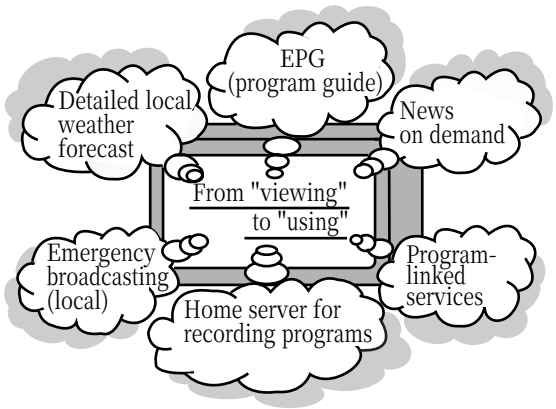


Fig. 1 Analog broadcasting and digital broadcasting

Digital broadcasting offers viewers numerous advantages, including the following:

- High broadcast quality (audio quality and image quality)
- Efficient utilization of frequencies (increased number of channels)
- High number of value-added services (multimedia services)

NHK Science & Technical Research Laboratories presented concepts of digital broadcasting services in their annual exhibition in 1999. The key concept was "useful digital broadcasting," or a shift from "viewing" to "using." The following figure illustrates the concept:



* Weather: Enables users to retrieve local weather forecasts by entering a postal code or telephone number.
* EPG: Provides program guides that enable users to select, find, or reserve programs.
* News: Enables users to view news without having to select a particular news program.
* Emergency: Overlays the current displays with relevant emergency information during regular programming.
* Server: Enables users to view a program from the beginning even if it has already started.
* Linkage: Provides details about programs, such as the names of featured personalities.

Fig. 2 Useful digital broadcasting

So that mobile receivers can also offer the above advantages, some mobile broadcast systems have a variety of features, including the following:

- Synchronization for reliably capturing radio waves as

the receiver moves

- Powerful error correction to eliminate errors caused by noise or other factors
- Selection of transmission parameters considering the possibility of multipath reception.

3. Technologies Used in Digital Broadcasting

Digital broadcasting is implemented with a variety of technologies. They can be classified into the major categories given below, which differ slightly depending on the broadcasting method and the conditions specific to the country that developed the method:

- Information source encoding technologies

Technologies for encoding (digitizing) audio and image data. Moving Picture Experts Group (MPEG) and other high-efficiency compression technologies are often used.

- Multiplexing technologies

Technologies for integrating several encoded information sources into a single data item so that the sources can be linked to each other

- Transmission path encoding technologies (modulation and error correction)

Error correction using a pre-appended code to correct errors which might occur in the transmission path, and modulation technologies for superimposing data on radio waves

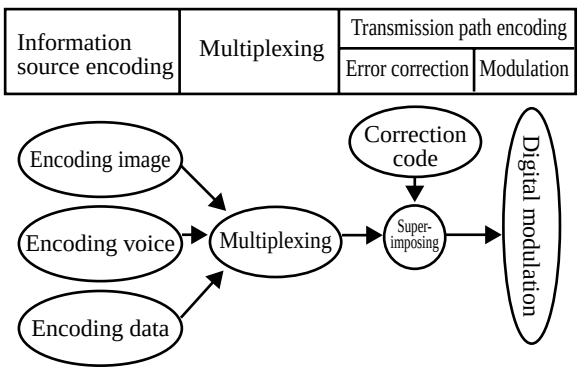


Fig. 3 Outline of technologies used in digital broadcasting

The following subsections describe the major multiplexing technologies and transmission technologies (modulation systems).

3.1 Multiplexing Technologies

Most broadcast systems have chosen to use MPEG2-Systems (ITU-T H.222.0 and ISO/IEC 13818-1) for multiplexing.

MPEG2 is widely used as the technology for Video and Audio compression. The MPEG2-Systems standard, however, also stipulates a method of multiplexing.

MPEG2-TS (transport stream) is a variation for broadcast use. Its data structure is included in MPEG2-Systems, and it is also an international standard. Fig.4 illustrates the concept of MPEG2-TS.

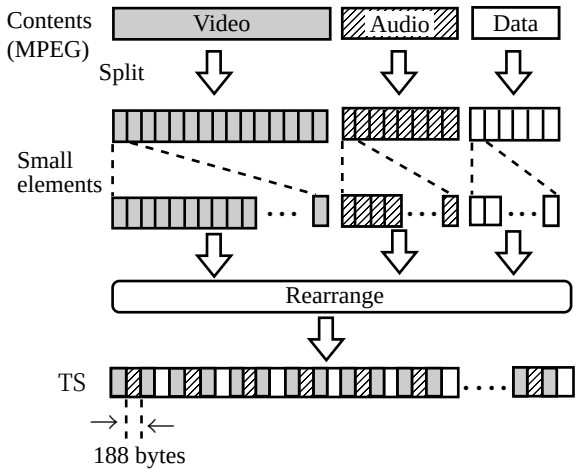
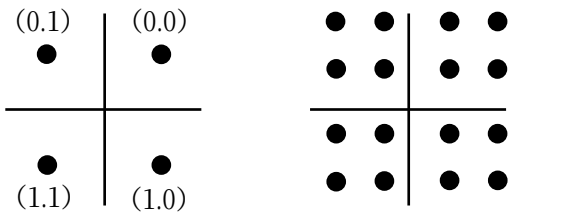


Fig. 4 Concept of MPEG2-TS

3.2 Transmission Path Encoding Technologies

Before reaching the receiver for reproduction, multiplexed data (information) may be exposed to many types of interference that might result in loss of data. To prevent this problem, the broadcast system uses error correction technology to ensure that the data can be restored if the degree of the error remains below a specified level.

Data with an error correction code appended is digitally modulated using a method such as Phase Shift Keying (PSK), Quadrature PSK (QPSK), and Quadrature Amplitude Modulation (QAM: Fig.5).



QAM symbol positions 16QAM symbol positions

Fig. 5 QAM symbol positions

The digitally modulated data is superimposed on carrier waves for broadcasting. Some systems use a single carrier wave (single-carrier systems) and others

use multiple carrier waves (multicarrier systems). Many multicarrier systems use orthogonal frequency division multiplexing (OFDM), described later.

4. Digital Broadcasting Worldwide

The digitization of broadcasting is a worldwide trend. Europe is moving ahead of other countries, having already implemented satellite and terrestrial broadcasting via digital modulation.

Table 1 Digital broadcasting in major countries

	Name	Broadcasting		Started in	Mobile reception
Europe	DVB-T	TV	Terrestrial	1998	△
	DVB-S	TV	Satellite	1998	×
	DAB	Audio	Terrestrial Satellite	1997	○
U.S.	IBOC	Audio	Terrestrial	To be determined	○
	Sirius	Audio	Satellite	2001	○
	XM	Audio	Satellite	2001	○
Japan	ISDB-S	TV	Satellite	2000	×
	ISDB-T	TV Audio	Terrestrial	2003	○
	MSB	TV Audio	Satellite	2002	○

Note: Future years indicate planned schedules.
* DVB: Digital Video Broadcasting
* DAB: Digital Audio Broadcasting (Eureka-147)
* IBOC: In-Band On Channel
* Sirius: Sirius Satellite Radio
* XM: XM Satellite Radio
* ISDB: Integrated Service Digital Broadcasting
* MSB: Mobile Satellite Broadcasting

Europe was the first to implement digital terrestrial broadcasting by applying a method called Digital Audio Broadcasting (DAB). The Eureka-147 project in Europe, which has been leading the development of DAB, started broadcasting in 1997. In the U.K., this broadcasting currently covers 65% of the population. With the exception of the U.S. and Japan, numerous countries outside Europe have also adopted this method and are moving toward implementation.

The U.S. is developing a digital broadcast system using a method different from DAB.

The U.S. has an extraordinarily large number of FM and other radio stations that are relatively small in terms of business scale. The country is, therefore, developing a system that allows digitization within the frequency band assigned to analog broadcasting, and promoting digitization in accordance with the specific conditions of each broadcasting station. Fig.6 illustrates the system, called In-Band On Channel (IBOC).

Table 2 DAB coverage in major countries

Country	Covered population	Country	Covered population
Belrium	80%	Canada	30%
Denmark	30%	Germany	30%
Finland	40%	Poland	8%
France	26%	Suth Africa	28%
Italy	10%	Sweden	80%
Spain	30%	Singapore	100%

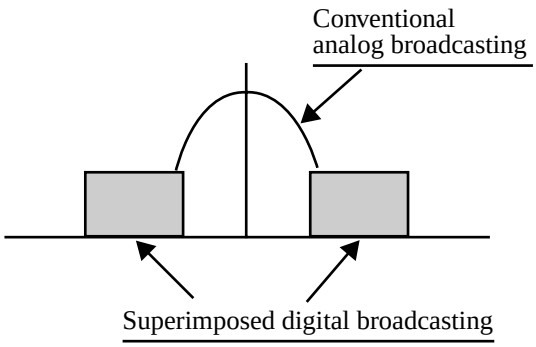


Fig. 6 Concept of IBOC

In addition, the U.S. has a well-developed road network, which allows people to drive very long distances that are almost impossible to visualize in Japan. When people drive across a service area, they cannot continue to view or listen to the same program being broadcast in that particular area. Currently, attention is being focused on digital radio broadcasting via satellite that, as a service that can be received anywhere in the country, is expected to solve this kind of problem.

Currently, two companies (XM Satellite Radio and Sirius Satellite Radio) are developing digital satellite radio broadcasting and will start broadcasting in 2001.

In Japan, digital terrestrial television broadcasting will start in the three metropolitan areas (Tokyo, Nagoya, and Osaka) in about 2003. Digital terrestrial audio broadcasting will start a little earlier.

Japanese digital terrestrial broadcasting (ISDB-T) will have the following features:

- Less susceptible to ghosts (interference)
- Supporting a single-frequency network (SFN)
- Allowing for mobile reception
- Providing layered transmission enabling selection of a modulation system

ISDB-T is classified into wide-band ISDB-T, which uses the same frequency band as that currently used for television broadcasting, and narrow-band ISDB-T, which divides this band for use of a narrower frequency band.

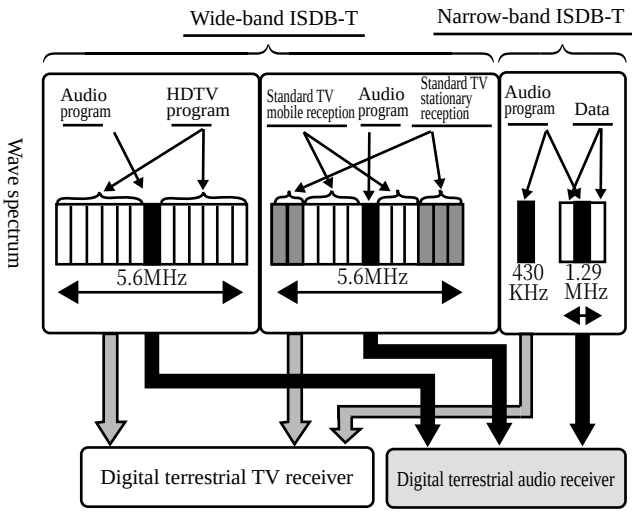


Fig. 7 Transmission using ISDB-T

5. Digital Mobile Broadcasting and Fujitsu TEN's Efforts

This section outlines digital broadcast systems developed for mobile receivers, mainly DAB, and introduces Fujitsu TEN's efforts to implement digital mobile broadcasting.

5.1 Outline of DAB

DAB broadcasts signals using a multicarrier system with OFDM, which is suitable for mobile reception.

OFDM is a method that splits information to be sent into multiple carriers digitally modulated via QPSK or QAM (Fig.8).

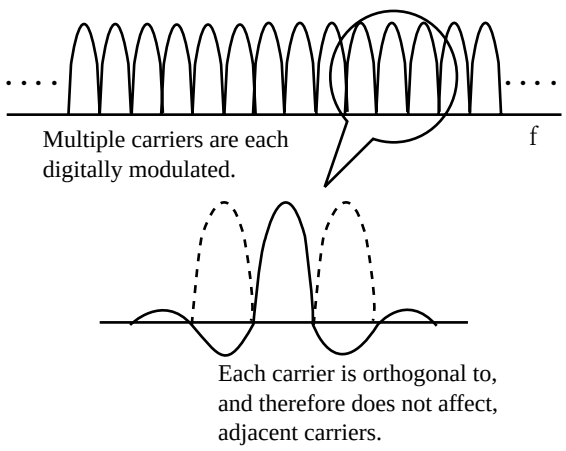


Fig.8 Concept of OFDM

OFDM uses fast Fourier transformation (FFT) for demodulation. An extra interval, called a guard interval (see Fig.9), is added to provide redundancy for the duration required for FFT, so that OFDM is less susceptible to multipath reception or phasing, resulting in high reception performance on mobile receivers.

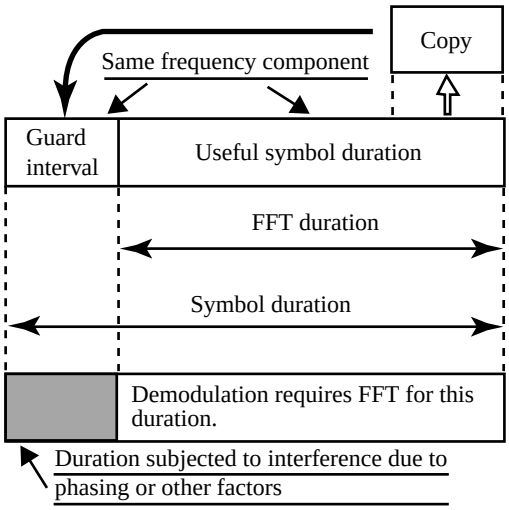


Fig. 9 Concept of guard intervals

As shown in Fig.10, DAB compresses the audio data to be broadcast and applies error correction encoding. It then applies frequency interleave and time interleave so that errors will not be centered at a particular point, thus improving resistance against reception failures. Finally, it multiplexes and modulates signals and sends them using OFDM.

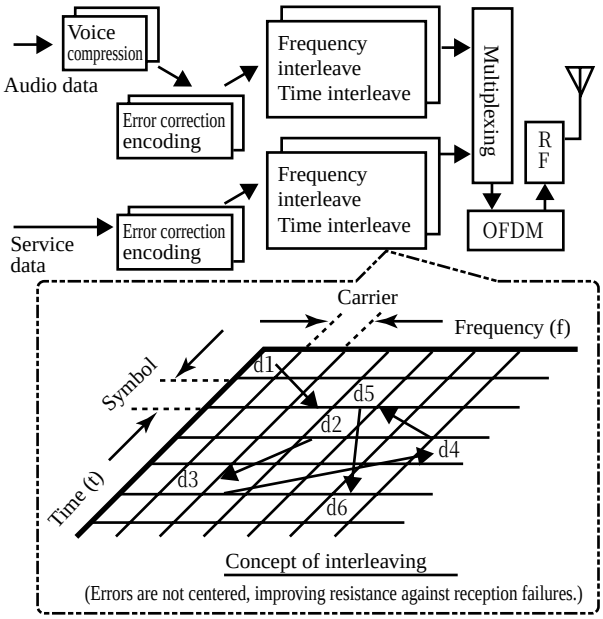


Fig. 10 DAB configuration

Fig.11 shows the transmission format of DAB. Optimum parameters (Table 3) are standardized in accordance with the broadcasting conditions, including the frequency band and whether broadcasting is terrestrial or via a satellite.

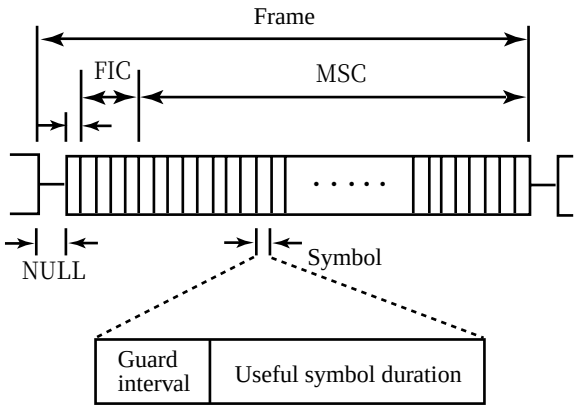


Fig. 11 DAB transmission format

Table 3 DAB transmission parameters

Transmission mode	Mode I	Mode II	Mode III	Mode IV
Number of symbols	76	76	153	76
Bandwidth	1536KHz	1536KHz	1536KHz	1536KHz
Number of carriers	1536	384	192	768
Carrier spacing	1KHz	4KHz	8KHz	2KHz
Frame length	98ms	24ms	24ms	48ms
Null duration	1.297ms	32us	168us	652us
Useful duration	1ms	250us	125us	500us
Guard interval	246us	62us	31us	123us
Purpose	SFN	Terrestrial	Satellite	Terrestrial
Frequency band	〈375MHz	〈1.5GHz	〈3GHz	〈1.5GHz

Notes:
1. The total transmission capacity is 2.3 Mbps.
2. Transmission mode IV has been added at the request of Canada.

5.2 Developing DAB Receivers

In contrast with analog broadcasting, digital broadcasting reception requires a more sophisticated analog stage and complex digital signal processing.

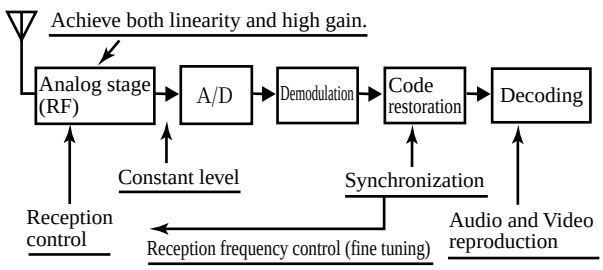


Fig. 12 Reception block for digital broadcasting

The analog stage must supply received signals required for digital signal processing at a correct, stable level. Digital-signal processing requires receiver control as well as synchronization, code restoration, decoding, and other processing.

Fujitsu TEN started collecting information related to this field at about the time digital broadcasting was first planned, and has been developing receivers supporting European DAB because this was the first infrastructure in the world to be implemented.

We are implementing DAB receiving functions in smaller, modularized units. The developed receivers are being tested for performance and conformance in Europe and Canada.

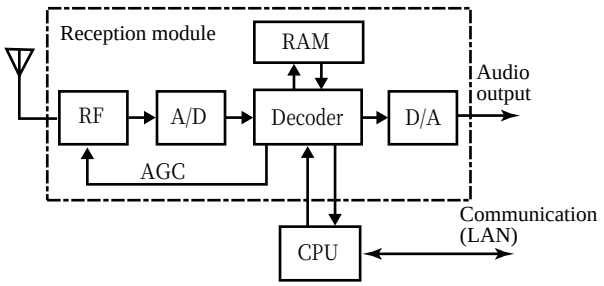


Fig. 13 Configuration of a developed DAB receiver

Fig. 14 Appearance of a developed DAB receiver

5.3 Developing Receivers for Digital S-Band Satellite Audio Broadcasting

Digital S-band satellite audio broadcasting, also called mobile satellite broadcasting (MSB), has been developed as Japan's first audio broadcast system for mobile receivers. Fujitsu TEN and other related companies have established an MSB preparatory company, with plans in place to start broadcasting in about 2002 or 2003.

MSB is digital audio broadcasting using a geostationary satellite that will be launched and positioned over Japan. This type of broadcasting transmits signals by applying the coding division multiplex (CDM) method in the 2.6 GHz band (S-Band).

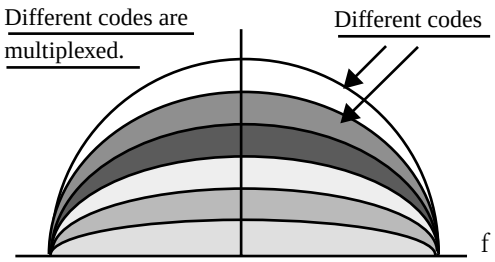


Fig.15 Concept of CDM

MSB provides nationwide broadcasting using a satellite. Because MSB will provide services in a format different from that for analog broadcasting, and because the services will start throughout Japan at the same time, development is scheduled so that receivers are available when broadcasting is started. We have studied a number of methods and completed the rough design of the receivers, and are currently engaged in specific development and design efforts.

5.4 Developing Digital Terrestrial Broadcasting Receivers

Of the two categories of digital terrestrial broadcasting, wide-band ISDB-T focuses on high-definition television broadcasting for stationary stations, while narrow-band ISDB-T aims to provide extensive mobile services, as additional services for FM broadcasting. Against this background, we are placing a higher priority on the development of narrow-band ISDB-T. We have studied a number of methods and completed the rough design of narrow-band ISDB-T receivers, and are currently engaged in development and design considering future receiver requirements.

6. Conclusion

Broadcasting, communication, and information technologies will change substantially in the next five years or so, during which time we will be promoting the digitization of broadcasting. This innovation must also be incorporated into car-mounted equipment. Car-mounted equipment, however, has its specific needs. Digital broadcasting will have to be integrated with other media to be mounted in cars. There will be a need for certain technologies, including those as for finding and providing information required by the user from a tremendous amount of information transmitted, and for providing information safely and uniquely. Fujitsu TEN will develop digital broadcasting receivers taking these requirements into consideration.

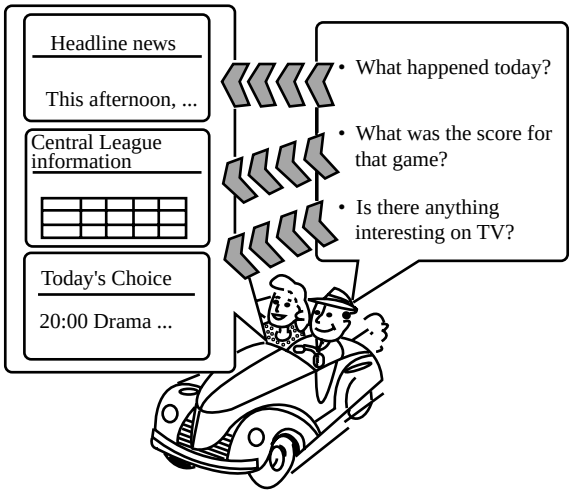


Fig. 16 Car-mounted receiver as an information supply terminal

References

Broadcasting Technologies, October 1998 to December 1999
Materials presented at the NHK Science & Technical Research Laboratories exhibition
ETS 300 250, EBU
ARIB STD B10, ARIB
ARIB STD B24, ARIB
etc.

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