NOTE

The approach to digital terrestrial TV broadcasting at Fujitsu TEN

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Abstract

Digital terrestrial TV broadcasting began in December 2003 over a partial region of three metropolitan areas (Tokyo, Nagoya and Osaka).

These technical notes provide an introduction with respect to the following points, regarding digital terrestrial TV broadcasting, for which nationwide deployment is planned by the end of 2006:

- Features of digital broadcasting
- Digital broadcasting measures in Japan
- A simple technical explanation with respect to the Japanese digital terrestrial TV system

Measures at our company (2000 to 2003)

1 Introduction

Digital terrestrial TV broadcasting began in December 2003 over a partial region of 3 metropolitan areas (Tokyo, Nagoya and Osaka) of Japan. This technical note provides everything from an introduction to the necessity of digital broadcasting and an overview of digital broadcasting, to related activities at our company up to 2003.

2 Why digital broadcasting?

With digital broadcast systems, global changeover (United Kingdom/United States/Sweden/South Korea and so on) from analogue to digital systems is progressing for the following reasons:

- Large-scale reductions of frequency usage are possible in comparison with analogue systems, and re-allocation of frequency is possible following termination of analogue broadcasting.
- The audience can enjoy a variety of services that cannot be offered using analogue broadcasting.

3 What is digital broadcasting?

Conventionally, analogue broadcasting was common, with AM (amplitude modulation) and FM (frequency modulation) transmission continuously of consecutive signals as is. Contrasting with this is digital broadcasting, a system of transmission using various encoding and multiplexing technologies for discrete signals.

The following new services can be realized through digitalization of broadcasting:

• High picture quality/high sound quality

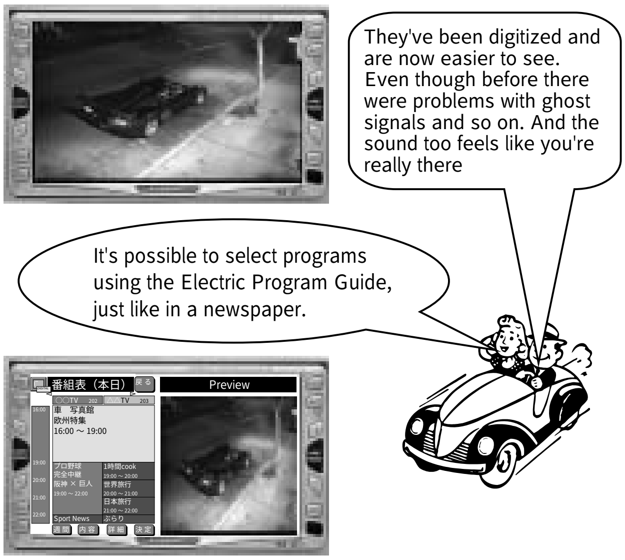
One can enjoy even more beautiful, powerful visual (high-vision) and sound quality (on par with CD). A high-quality broadcasting can be ensured, with no more ghost images.

• Multiple channels

Many programs can be broadcasted over the same bandwidth used for analogue broadcasting because of the high frequency efficiency.

• Advanced functionality

Through data broadcast functions, it is possible to watch a baseball game while checking player information or detailed information on the progress at other baseball stadiums. Also, weather information, news and so on can be gathered whenever one wishes. And with bidirectional functionality, it becomes possible to participate in quiz shows, to cast the deciding vote during the annual NHK sponsored year-end men versus women singing contest, to reply to questionnaires on television programs, and to enjoy other novel forms of entertainment.



＊The image displayed above is an image embedded.

Fig.1 The digital broadcasting image

4 Japanese digital broadcasting

In discussing Japanese digital TV broadcasting trends, CS (Communications Satellite) digital broadcasting, utilizing satellite and typified by SKY PerfecTV ! , began in 1996. Following this and the BS (Broadcasting Satellite) digital TV broadcasting of 2000, typified by WOWOW, preparations are now underway for the start of mobile broadcasting (satellite digital radio) in July 2004.

At the same time, in terms of digital terrestrial TV broadcasting, the so-called ISDB-T (Integrated Services Digital Broadcasting Terrestrial) expanded according to plan in a groundbreaking move in December 2003 to encompass 3 partial metropolitan areas, and plans are being pursued for nationwide deployment by the end of 2006. Existing analogue broadcasting is expected to cease transmission by July 2011. Table 1 shows the number of digital TV broadcast receivers shipped as of the end of February 2004. The BS/CS reception area is basically the entire country of Japan, and the number of units shipped averages 600,000 per year. On the other hand, while the reception area for ISDB-T is approximately 5% of the country, 607,000 units have been shipped in about 1 year, a very rapid diffusion of ISDB-T. (As of February 2004)

Table 1 Shipment of digital TV broadcast receivers in Japan

(Thousand units)

	ISDB-T	BS	CS
February 2004 (single month)			
Television with built-in tuner	67	39	—
Tuner	4	4	13
Total	71	43	13
Cumulative total by February 2004	('03 to FY1)	('99 to FY5)	('98 to FY6)
Television with built-in tuner	550	1995	—
Tuner	57	891	3899
Total	607	2886	3899

(Reference: JEITA and the Japan Satellite Broadcasting Association website)

ISDB-T utilizes the UHF (470 to 770MHz) band. Broadcasts are implemented with 13 segment partitioning of the same bandwidth used for conventional analogue broadcasting. HDTV (High Definition Television, Figures 2-a, b) is implemented using 12 or 13 of these 13 segments, making it possible to enjoy high-quality imaging. Also, by partitioning the 13 segments into a maximum of 3, partial reception[*1] for mobile units (simulcasts using H.264[*2]), utilizing 1 segment, and 2 SDTV programs (Standard Definition Television: conventional TV, Figure 2-c) become possible.

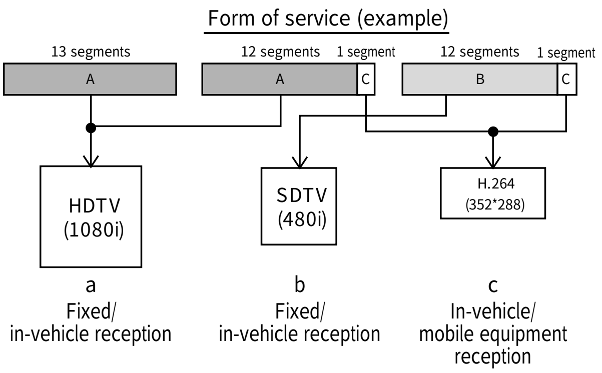


Fig.2 ISDB-T hierarchy transmission example

Features of ISDB-T include the following points:

- As the signal is resistant to the influence of noise and disturbances, presentation of high-quality images and sound is possible.
- 2 to 3 TV channels are possible in the same bandwidth used for 1 channel of conventional analogue TV. As well, the modulation method can be selected for each channel.
- Reception by mobile unit is possible over a wider range through adoption of a system resistant to multi-path interference and fading.
- The modulation method can be selected through layered transmission.
- Program search, reservation and selection are possible utilizing a program list (EPG: Electric Program Guide) similar to that found in newspapers.
- By accumulating information at the receiver while enjoying TV programs, it becomes possible to view information whenever one wants.
- With captions and explanatory programs, superior service is offered to the elderly and those with visual and auditory impairments.

5 Japanese digital broadcast technology

Three typical forms of technology utilized in ISDB-T are ① data technology source encoding, ② Multiplexing technology, and ③ Transmission path encoding technology (modulation and error correcting). Each form of technology is explained below.

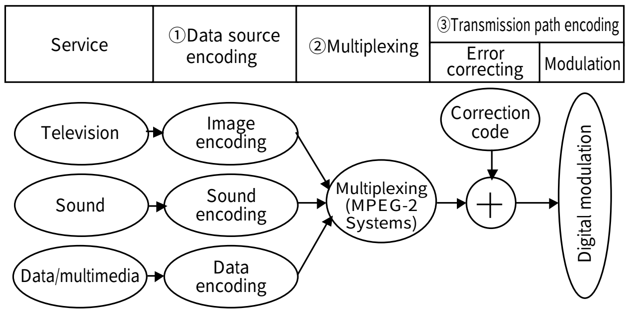


Fig.3 Summary of technology utilized in ISDB-T

5.1 Data source encoding technology

Data source encoding is a technique for the encoding of sound and/or images. It primarily utilizes the so-called MPEG (Moving Picture Experts Group) high-efficiency compression technique.

The systems in the table below are adopted in ISDB-T.

Table 2 Encoding methods utilized in ISDB-T

Image	MPEG-2 Video(MP@HL/MP@ML)
Sound	MPEG-2 AAC(profile: Low Complexity)

5.2 Multiplexing technology

This technology allows mutual coordination of data sources, with multiple encoded data sources joined into a single data stream. The so-called MPEG2-SYSTEMS method is adopted for ISDB-T. The MPEG2-SYSTEMS is a method for multiplexing the data from the encoded images, sound and data, and then playing them back syn-

(＊1) Only the band center segment is received. It is possible to enjoy a part of the broadcasting even if all of the segments are not received.
(＊2) The simultaneous broadcasting of the same program

chronously. MPEG2-SYSTEMS consists of PS (Program Stream) and TS (Transport Stream), and TS is applied in ISDB-T. PS is applied in DVD and other media.

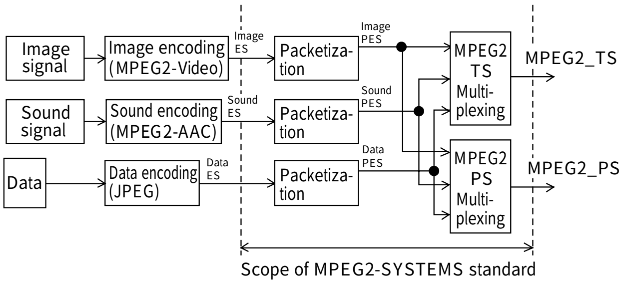


Fig.4 The range of MPEG2 SYSTEMS standards

5.3 Transmission path encoding technology (modulation and error correcting)

5.3.1 Digital modulation technology

In digital modulation, carrier wave amplitude, frequency or phase, or a combination of these factors, is changed in accordance with the digital signal (1 or 0).

There are 3 modulation methods as follows:

- **ASK(Amplitude Shift Keying):** Amplitude variation
- **FSK(Frequency Shift Keying):** Frequency variation
- **PSK(Phase Shift Keying):** Phase variation

With the above-mentioned methods, transmission of a large amount of data is not possible (1 bit per symbol). The following 3 methods are used as methods for transmission of a large amount of data:

- **QPSK(Quadrature Phase Shift Keying):** carrier wave phase is taken every 90 degrees, making 2 bit information transmission possible with 1 symbol.
- **DQPSK(Differential QPSK):** In contrast to the QPSK method, in which information is directly related to carrier wave phase, this is a differential phase modulation method in which information is encoded in the phase difference of the carrier wave. In this system, a synchronous carrier wave is not necessary at the receiver for demodulation.
- **QAM(Quadrature Amplitude Modulation):** This is a method for adding a variance to amplitude using 2 carrier waves with a phase difference of 90 degrees (orthogonal relationship). With 16 QAM, 4-bit data transmission is possible with 1 symbol, and with 64 QAM, 6-bit transmission is possible with 1 symbol.

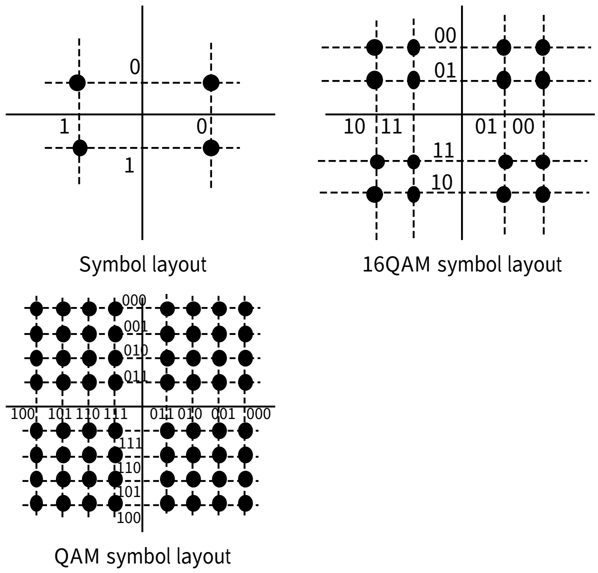


Fig.5 Symbol distribution by modulations

For ISDB-T, modulation is implemented via DQPSK, 16 QAM or 64 QAM modulation methods. In this case however, a multi-carrier system is adopted, utilizing multiple carrier waves. This method is generally what is known as OFDM (Orthogonal Frequency Division Multiplexing).

②With OFDM, good reception in mobile units is possible, which means resistance to multi-path interference and fading.

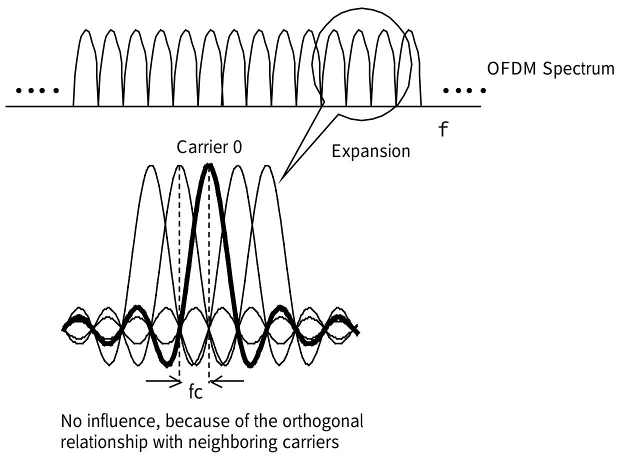


Fig.6 The OFDM Spectrum

Here, a simple explanation is given of OFDM, a characteristic of ISDB-T. When a portion of the OFDM spectrum is enlarged (Figure 6), it is found that a spectrum has multiple carrier overlaps. Here, application of an inverse Fourier transform to the digitally modulated carrier for the symbol period Ts (Figure 8), becomes multiple signals in row at a carrier interval of fc = 1/Ts. At carrier 0 center frequency, carriers to the left and right are zero. This suggests that there will not be even the slightest influence on the central frequencies of other carriers (i.e. the carriers are in a mutually orthogonal relationship). From this, by integrating an arbitrary carrier with that symbol period, extraction is possible without the influence of other carriers. Also, with OFDM, resistance to multi-path interference and fading is heightened by lengthening the symbol period Ts, which is to say by narrowing the carrier interval fc.

However, when the multi-path delay becomes large, sudden dropout occurs (Figure 7), influencing OFDM, which is utilized in the amplitude modulation. To minimize this influence, a Guard Interval is adopted.

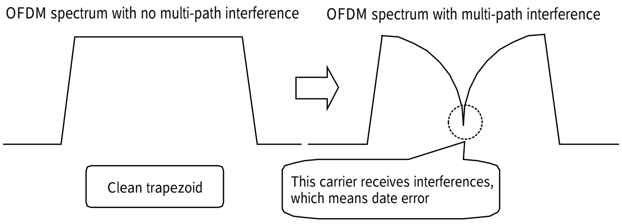


Fig.7 The OFDM spectrum, under multipath interference

The guard interval refers to a period in which phase and amplitude are varied in a complex manner through the influence of a reflected wave. Due to the guard interval, the various carrier frequency intervals are not changed, and the symbol length is only lengthened during the anticipated multi-path interference wave delay period. At the receiver, the guard interval data for which interference between symbols is expected due to multi-path interference is ignored. OFDM demodulation is implemented with the remainder of the data.

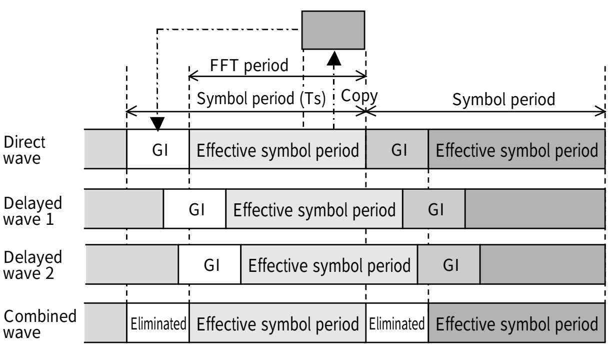


Fig.8 Guard interval conceptual diagram

Through this establishment of a guard interval, digital terrestrial TV broadcasting can be relayed using the same frequency as the so-called SFN (Single Frequency Network). In conventional analogue broadcasting, problems arose when the same frequencies were utilized due to the occurrence of mixed signals at neighboring relay stations. However, by utilizing OFDM, as interference does not occur if there is a delay within the guard interval, broadcast wave relay becomes possible without changing the frequency for each broadcast area.

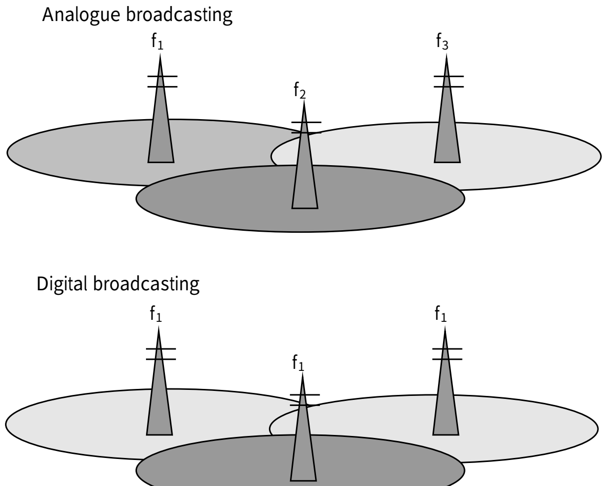


Fig.9 SFN conceptual diagram

5.3.2 Error correcting technology

Error correcting technology refers to techniques enabling the correction of errors through supplementary code that has anticipated errors occurring in the transmission path. In the case of ISDB-T, the following 2 types are utilized:

- **Viterbi Algorithm:** Even if an error occurs in the code series, correct decoding is possible, and correcting performance is high with respect to random errors.
- **Reed Solomon Code:** This is block coding of data blocks, for which multiple check bits are appended to the original data, in terms of correction units. Detection and correction can be implemented of burst errors (in which bit errors are produced intensively).

Table 3 shows prescribed transmission parameters for ISDB-T, and Tables 4 and 5 show anticipated layer transmissions, and television broadcasting and total transmission quantity. Table 6 shows the transmission parameters for the layer in Table 4.

Table 3 ISDB-T transmission parameters

Mode		Mode1*3	Mode2	Mode3
Segment		13		
Bandwidth (MHz)		5.575	5.573	5.572
Carrier interval (kHz)		3.968	1.984	0.992
Number of carriers		1405	2496	5617
Carrier modulation method		QPSK,16QAM,64QAM,DQPSK		
Number of symbols per frame		204		
Effective symbol length (s)		252μs	504μs	1.008ms
Guard interval		1/4,1/8,1/16,1/32 of effective symbol length		
Frame length		(Effective symbol length + Guard interval) ×204		
Error correcting	Inner code	Convolutioal code (Encoding ratio: 1/2,2/3,3/4,5/6,7/8)		
	Outer code	Reed-Solomon (204,188)		
Data bit rate (Mbit/s)		3.651 to 23.234		

Table 4 The anticipated relationship between the hierarchy transmission and digital TV broadcasting

Pattern	Possibility	Number of segments	Layer	TV broadcasting	
				HD	SD
1	○	13	A	◎	○
2	△	13	B	△	◎
3	○	1 (Partial reception)	C	—	—
		12	A	◎	○
4	×	2 to 8	B	×	△
		5 to 11	A	◎	△
5	△	1 (Partial reception)	C	—	—
		12	B	△	◎
6	×	1 (Partial reception)	C	—	—
		1 to 7	B	×	△
		5 to 11	A	◎	○

Table 5 The anticipated relationship between the hierarchy transmission and total transmission quantity

Pattern	Total transmission quantity (kbps)	
	Max.	Min.
1	21298.42	10953.41
2	10818.21	3651.05
3	624.13	280.85
	19660.08	10110.84
4	6657.36	561.70
	18021.74	4212.85
5	624.13	280.85
	9986.04	3370.20
6	624.13	280.85
	5825.19	280.85
	18021.74	4212.85

Table 6 Transmission parameters for each layer

Layer	Mode・Guard interval					Modulation・Error correcting				
	Mode3			Mode2		64QAM	16QAM		QPSK	
	1/4	1/8	1/16	1/4	1/8	Total encod-ing ratio	2/3	1/2	2/3	1/2
A	○	○	△	○	△	○	×	×	×	×
B	○	○	△	○	△	×	○	○	○	○
C	○	○	△	○	△	×	×	○	○	○

This section has offered an explanation of typical technology utilized in ISDB-T. Next, activities at our company are introduced for the realization of the characteristics of digital broadcasting - "high-quality imaging/high-quality sound", "multiple channels", "advanced functionality" - even in mobile units, using these techniques.

6 Activities at our company

With respect to ISDB-T, practical test equipment (from this year focusing on ISDB-T development) was developed in 2000. Following this, prototype equipment was delivered to TOYOTA MOTOR CORPORATION during 2001 to 2003.

Our company's road map is shown in Figure 10.

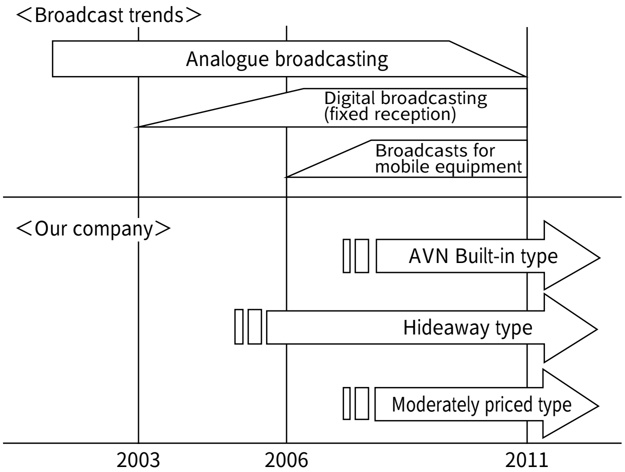


Fig.10 Road map of our company

6.1 Difference between mobile receivers and receivers for home use

Receivers for mobile units differ greatly from receivers for home use in terms of the conditions required.

6.1.1 Display system

As in-vehicle displays are generally smaller than displays for home use, characters are smaller when showing data broadcasting on in-vehicle displays, and there is possibility of problems reading the information.

(*3) They exist as rules, but have not been used.

At our company, enlargement functions have been established utilizing image processing techniques, improving the visibility.

Also, with receivers for home use, often the television screen is the only one displayed when watching television (simultaneous display of video, DVD and other external input is rare). In the vehicle, the superposition display of navigational screens, operating menus and other screens is increasingly being implemented.

Figure 11 shows an example of a combination of operating menu screen and television screen and an explanation is offered of one example of image processing techniques at our company.

Fig.11 Superposition indication example

The screen shown in Figure 11 comprises 3 layers. A layer is a like a canvas used when painting a picture. The combined screens comprise multiple layers. Also, an order of priority is assigned to each layer. The top ranking layer is displayed in the foreground, with the lower-ranking layers covered by the upper-ranking layers and not visible. Display of the lower-ranking layer is possible by making the upper-ranking layer transparent. The layers in the screen shown in Figure 11 have the following definitions:

Layer 1: Frame (SW and so on) portion
Layer 2: Wallpaper (background image) portion
Layer 3: Moving image portion (output from video decoder)

With the exclusion of uniquely varying items such as the broadcast station name and program name, all other parts are stored in Flash Rom as bitmap data. Each time the screen is called, the necessary portions are called from Flash Rom, and are pasted to layer 1. Transparency processing is implemented for all but the pasted portion, and low-priority screens (layers 2 and 3) become visible. Layer 2 is painted with the wallpaper color. The portion overlapping with layer 3 is removed with a rectangle. A reduction process is implemented on the television image, and it is displayed on layer 3.

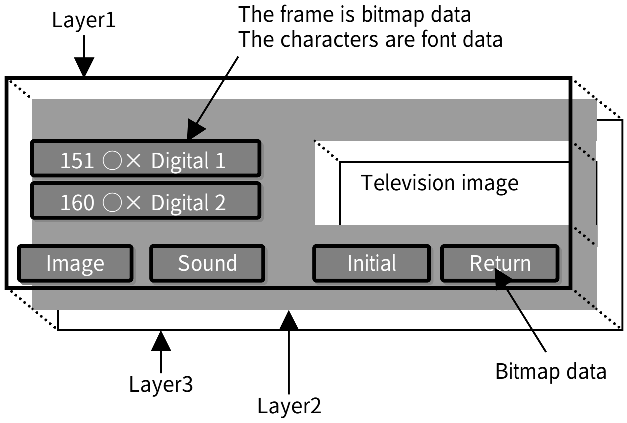


Fig.12 Superposition technology

6.1.2 Operating system

Receivers for home use are all operated using remote controls. In the vehicle however, use of remote controls is avoided, for fear of loss, and because operation is problematic due to speed changes and left/right turns. At our company, we have developed soft remote control via touch switches on the screen, utilizing the benefits of the short distance from the display. Figure 13 shows an example of soft remote control display, and Figure 14 shows an example of soft remote control operation.

Fig.13 Software remote control indication example

The following measures have been taken in order to improve operability via soft remote control

- Change in the display position of operating switches is possible so as to avoid occluding data broadcast characters.
- Cyclic displays are adopted, in order to avoid displaying multiple buttons all at once

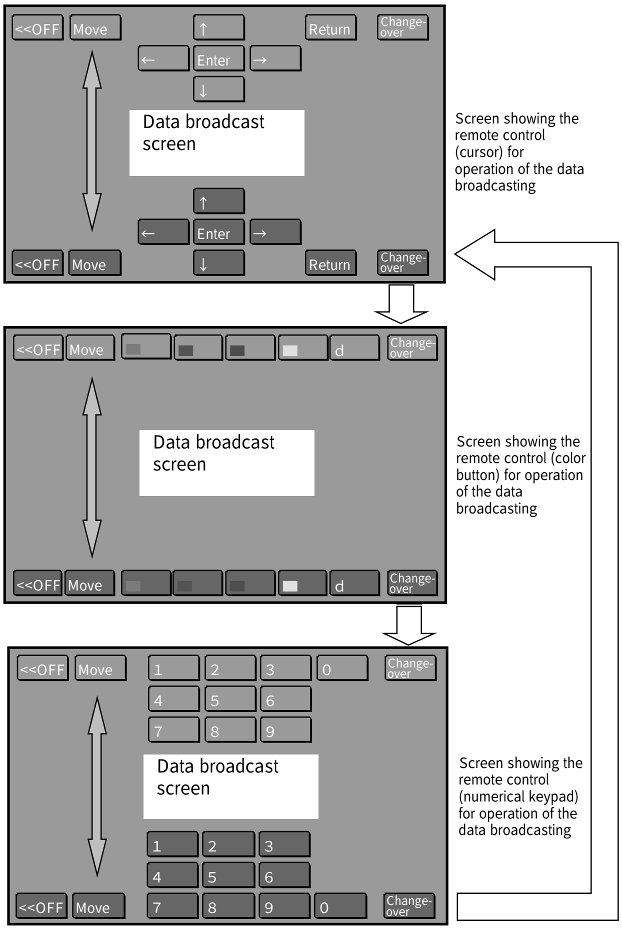


Fig.14 Software remote control transition example

6.1.3 Receiver system

When receiving at home, multi-path interference is reduced by using directional antenna facing the radio wave arrival direction (direct waves), enabling stable reception. Also, there is no frequency shift from the Doppler Effect. Conversely, non-directional antennas are utilized for vehicle use, as the radio wave arrival direction is not specified. For this reason, both the direct wave and the wave delayed due to multi-path interference are received at the same instance, and as explained earlier, the OFDM spectrum is ruined. Further, a Doppler shift occurs due to movement, and the reception becomes unstable.

Based on these conditions, at our company, reception performance has been improved with antenna control techniques utilizing multiple antennas.

6.2 Prototype equipment

The structure of prototype equipment developed is shown in Figure 15.

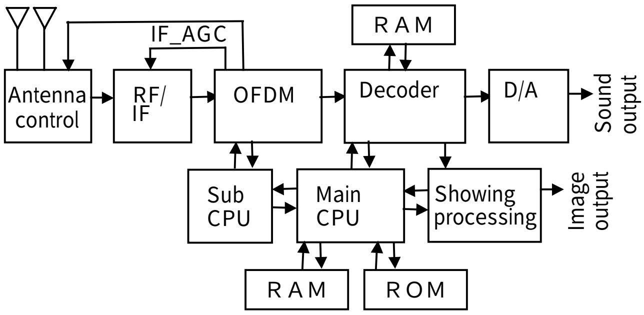


Fig.15 Structural diagram for the ISDB-T receiver developed

Next, the characteristics are described of prototype equipment for which development was implemented in 2001 to 2003.

In 2001, basic receiver functionality was realized. With back-end parts, a decoder peripheral circuit was completed, confirming the MPEG 2 Video/AAC output. The photograph in the summary section is an outline drawing of the equipment.

In 2002, development proceeded in order to further improve receiver performance, data broadcast response, and partial reception response.

Improvements in operability via touch switches, and compliance with multiple image output (NTSC/RGB/D2/Digital RGB) were realized. Figure 16 is the outline drawing for the prototype developed in 2002.

Fig.16 2002 prototype outline

In 2003, this broadcasting also began over a partial area of 3 metropolitan areas of Japan, and prototypes were developed with a form even closer to a final product. With this prototype, exclusive ASIC developed was also implemented with the intension of reducing costs and improving performance.

7 Conclusions

In this technical note, a simple introduction has been given to the features of digital broadcasting, and related measures to date at our company.

In conventional analogue broadcasting, it was not possible to watch TV programs without noise during movement. Conversely, with digital broadcasting, while there are image degradation locations, the quality is equivalent to that of DVD, even when in movement. There are promising systems that will increase enjoyment for the viewer in future, including enlarged, high-definition in-vehicle displays.

Also, with analogue broadcasting, it was not possible to conceive of additional applications beyond the passivity of viewing television. With digital broadcasting however, active uses can be considered beyond television viewing, including acquisition of information, and participation in broadcasting. Even excluding reception performance, convenient in-vehicle can be considered an integral aspect of product value.

In future, with digital broadcasting the possibilities lie hidden for the creation of contents never before seen. We are pursuing the development of new receivers utilizing the never before seen merits of digital broadcasting, and are developing technology which will quickly ensure a No. 1 position.

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