Mobile Terminals Supporting Satellite Digital Radio Broadcast

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*We have developed the "FOMA D851iWM," a series of mobile terminals supporting "MobaHO!™*1" satellite digital radiobroadcast service. In addition to "MobaHO!" reception functions, D851iWM mobile terminals feature advanced music functions, including FM radio reception and functions to download songs on commercially available music CDs from PCs for playback.*

1. Introduction

As part of the digitalization of broadcast service, the "MobaHO!" satellite digital radio broadcast service was launched in October 2004.

There are many broadcasting companies such as NHK and various commercial broadcasters currently involved in terrestrial digital broadcasts. Consequently, the satellites for satellite digital radio broadcast services are being operated in cooperation with South Korea, and unique standards have been implemented for each country by changing planes of polarization and other methods; these services are provided by Mobile Broadcasting Corporation within Japan and by Tu Media Corporation affiliated with SK Telecom in South Korea. **Table 1** shows the basic specifications of satellite digital radio broadcast.

Until now, satellite broadcasts were typically received by setting up parabola antennas. Conversely, "MobaHO!" allows broadcast reception with compact antennas due to significantly higher satellite output power compared to conventional Broadcasting Satellites (BS) and Communications Satellites (CS).

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*1 MobaHO!™: MobaHO! and their logos are trademarks or registered trademarks of Mobile Broadcasting Corporation.

Table 1 Basic specifications of satellite digital radio broadcast

Frequency	2,630 to 2,655 MHz (25 MHz band)
Modulation method	CDM modulation scheme
Diffusion method	Walsh encoding and shortened M-sequence
Data rate	7 Mbit/s or higher (30 code multiplex)
Video encoding scheme	H.264
Audio encoding scheme	MPEG-2 AAC
Multiplexing method	MPEG-2 System
Broadcast contents	Video broadcast, sound/music broadcast, data broadcast

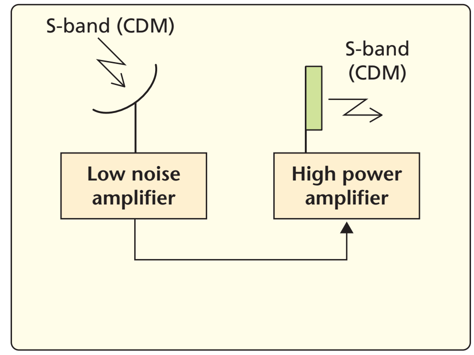
Walsh code: A method of generating pseudo-random numbers used to divide channels.
Shortened M-sequence: A method of generating pseudo-random numbers used in multi-path analysis.
MPEG-2 System: Signal multiplexing system defined by MPEG-2 allowing the transmission of multiple data items via one transmission channel at the same time.
H.264: An encoding scheme for video data.

Moreover, various measures are being taken to complement the services, such installing the so-called "Gap Filler (GF)" devices placed on the rooftops of buildings for relaying broadcast waves from the satellites and resending the waves to provide services to targets that tend to be located outside the direct range of the satellite broadcast, such as behind buildings and vehicles in urban areas. **Figure 1** shows an overview of the GF. There are two types of GF: one that adopts a repeater system that directly amplifies broadcast waves transmitted from a satellite to mobile terminals in the S-band (2.6 GHz band) and sends them to the mobile terminals, and one that adopts a regenerative relay system where the GF device demodulates relay signals transmitted from a satellite in the Ku-band (12 GHz band), converts them to the S-band, and then sends them to the mobile terminals.

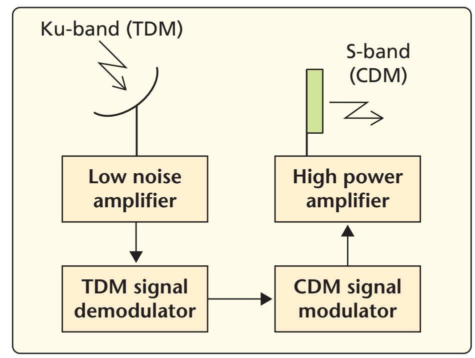
Since the power level of signals relayed through GF devices is higher than the power level of waves received directly from a satellite, it is possible to use compact antennas for reception. Therefore, we focused on developing a compact and lightweight mobile terminal with the "MobaHO!" reception function added to the basic functions of FOMA in the D851iWM.

2. Overview of D851iWM Terminals

We developed the D851iWM based on the following concepts:



(a) Repeater system



(b) Regenerative relay system

TDM: Time Division Multiplexing

Figure 1 GF overview

- In the "MobaHO!" services, video programs and data broadcasting are provided in addition to radio programs. However, we chose to restrict our focus to "music mobile terminals" and developed functions to receive radio programs.
- The hardware and software used for the FOMA 902i series were adopted to the greatest extent possible to achieve stable quality in the early stages and reduce cost.
- The ideas of various external designers were incorporated in the design of chassis and other elements. In order to limit the size and weight to compare favorably in terms of the latest mobile terminal design, the antennas were built into the main body instead of structures with protruding antennas.

Photo 1 shows the external view of the D851iWM, and **Table 2** shows the basic specifications. We implemented a new

Photo 1 External view of the D851iWM

hardware platform for the D851iWM that accommodates the following “MobaHO!” technologies.

1) Modulation Method

“MobaHO!” adopts Quadrature Phase Shift Keying (QPSK)[*2] as its digital modulation method and Direct Sequence-Code Division Multiplex (DS-CDM)[*3] as its transmission channel encoding method. The DS-CDM method can alleviate such factors that deteriorate reception quality as fading in multi-path propagation channels. Since this method can also ensure stable reception quality even at high speeds, it is obviously suited for mobile reception.

2) Encoding Scheme

For the audio encoding, Moving Picture Experts Group phase 2 (MPEG-2)[*4] Advanced Audio Coding (AAC)[*5] is used. The MPEG-2 AAC scheme offers higher compression efficiency than the MPEG-2 Backward Compatible (BC)[*6] scheme and can obtain higher quality at low bit rates than MPEG Audio Layer-3 (MP3)[*7] and other formats. Furthermore, the “MobaHO!” audio encoding includes Spectral Band Replication (SBR)[*8] processing to improve sound quality at low bit rates. Note that MPEG-2 AAC is also used as the audio encoding scheme for terrestrial digital broadcasts.

Moreover, the D851iWM supports the following additional functions to improve its marketability.

1) Ripped Music File Playback Function

As a music mobile terminal, the D851iWM supports the playback of music files ripped from CDs. The formats supported include Adaptive Transform Acoustic Coding 3 (ATRAC3)™[*9], ATRAC3 plus™[*10], AAC, and MP3. Moreover, the built-in IC dedicated for playing music helps reduce power consumption while playing music files ripped from CDs, thus allowing about 20 hours of continuous playback. Special soft-

Table 2 Basic specifications of the D851iWM

	D851iWM	D902i
Size	109 × 50 × 24 mm	109 × 50 × 19.5 mm
Weight	App. 136 g	App. 116 g
Continuous standby time	Stationary: About 420 hours In transit: About 320 hours	Stationary: About 550 hours In transit: About 380 hours
Continuous talk time	Voice communication: About 170 minutes Videophone: About 90 minutes	Voice communication: About 165 minutes Videophone: About 90 minutes
Continuous playback time	Files ripped from CDs: App. 20 hours Files recorded from “MobaHO!”: App. 6 hours	
Continuous listening time	“MobaHO!”: 120 minutes FM radio: App. 25 hours	
LCD screen	App. 2.8 inch (400 × 240 dots)	App. 2.8 inch (400 × 240 dots)
Camera	Main: Effective resolution 300,000 pixels (CMOS)	Main: Effective resolution 2,000,000 pixels (CCD) Sub: Effective resolution 300,000 pixels (CMOS)
Other functions	“MobaHO!” listening function (audio only) Ripped file playback function FM radio function	FeliCa® PushTalk

FeliCa®: Registered trademark of Sony Corporation.

*2 QPSK: A digital modulation method that allows transmission of 2 bits of information at the same time by assigning one value to each of four phases.

*3 DS-CDM: A method that uses different diffusion coding for each user to diffuse information into broadband transmission and multiplexes signals from multiple users in the same frequency band and time slot.

*4 MPEG-2: A coding scheme for moving-picture data used for DVD and other storage media, as well as satellite broadcast.

*5 AAC: An audio encoding scheme with high compression efficiency, used in moving-picture coding systems such as MPEG-2 or MPEG-4.

*6 MPEG-2 BC: An audio encoding scheme. This is used in MPEG-2 and has the same compression method as MP3 (see *7). Unlike MP3, it supports 5.1 channel surround sound.

*7 MP3: An audio compression technology defined by MPEG-1. This compresses the data volume to approximately 1/10 of the data volume on music CDs, while maintaining the same sound quality as music CDs.

ware is also provided for ripping music files from CDs and downloading them to the D851iWM.

2) FM Radio Listening Function

The D851iWM supports a function for listening to FM radio programs up to about 25 continuous hours.

3) Media Switching Function

As a music mobile terminal, the D851iWM is equipped with a special key allowing the user to switch among the "MobaHO!" listening function, music player function, and FM radio function with a single touch.

4) 1 GB Built-in Memory

The D851iWM is equipped with 1 GB of built-in memory for storing music files. Both files ripped from CDs and files recorded from "MobaHO!" can be stored in this memory.

3. Overview of Satellite Digital Radio Broadcast Listening Functions

The "MobaHO!" listening functions we built into the D851iWM are explained below.

3.1 Technical Issues in Wireless Zones and Solutions

1) Power Consumption of Code Division Multiplex (CDM) Tuner

For radio channels, "MobaHO!" uses CDM as the modulation method which differs from the QPSK/16 Quadrature Amplitude Modulation (16QAM)[*11]-Orthogonal Frequency Division Multiplexing (OFDM)[*12] method adopted in terrestrial digital TV broadcasts. Regarding the CDM tuner used for "MobaHO!," we feared that the large amounts of power consumed by domestic products would significantly shorten the original call time if we were to implement such products in our mobile terminal. Enlarging the battery size to compensate for the power consumed by the CDM tuner was not realistic either, since it would adversely affect the marketability of the mobile terminals.

For this reason, we conducted surveys in South Korea where mobile terminals for satellite digital radio broadcasts have already been commercialized and found out that CDM tuners were available from several manufacturers. Furthermore, some CDM tuners consumed particularly low power due to the use of Complementary Metal Oxide Semiconductor (CMOS)[*13] technology. Since tuners that fit to Japanese standards were available for import, we began evaluating the quality, functions, and other properties of these tuners.

Our evaluations revealed that these products consumed about half the power consumed by existing Japanese products, with roughly equivalent reception sensitivity. We thus determined that the mobile terminals could be successfully commercialized without having to enlarge the battery.

2) Contents Protection

As a charged service with a limited number of subscribers, "MobaHO!" introduces broadcast encrypting to prevent the illegal digital copying of content. We determined that it would be necessary to set up a new encryption mechanism to protect against the copying of content after the decrypting process, and then allow the recording of music programs on the mobile terminal.

We thus decided to encrypt all contents again when recorded in the built-in memory of the mobile terminal.

3) Required Input Level

For this mobile terminal, it is necessary to use compact antennas that can be built into the chassis, which is a design philosophy that directly counters normal reception level improvement measures. Since the antennas are smaller than that built into the existing "MobaHO!" dedicated receivers, it is difficult to obtain the required gain and concern regarding an insufficient input level, especially at locations far away from the GF devices (i.e., beyond the broadcast range).

For this reason, when designing the built-in antennas, we considered various situations in which the mobile terminal might be used, such as when held in the hand or placed in a pocket, and placed two antenna systems inside the chassis as far away from each other as possible so that the antenna with higher gain could be used in any given situation.When selecting antenna types, we decided to test several types including the helical chip antenna[*14] and reverse F-type antenna[*15]. We ulti-

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*8 SBR: A technology used to expand the playback bandwidth to significantly improve the effects of compression mainly at low bit rates.

*9 ATRAC3™: An audio compression technology. This supports copyright protection functions and compresses the data volume to approximately 1/10 of the data volume on music CDs, while maintaining the same sound quality as music CDs.
ATRAC3 and its logo are trademarks or registered trademarks of Sony Corporation in Japan and other countries.

*10 ATRAC3plus™: An audio compression technology. This is an improved version of ATRAC3 and allows obtaining twice as high compression ratios as ATRAC3, while maintaining the same sound quality as music CDs.
ATRAC3plus and its logo are trademarks or registered trademarks of Sony Corporation in Japan and other countries.

*11 16QAM: A digital modulation method that allows transmission of 4 bits of information at the same time by assigning one value to each of 16 different combinations of amplitude and phase.

mately selected a compact helical chip antenna with high gain. Still, it was found that the level of input to the tuner obtained via the built-in antennas was only at least 13 dB lower than the input level of existing "MobaHO!" dedicated receivers. This meant that relying solely on the built-in antennas would prove impractical in areas other than intense electric field areas, and we determined that it was necessary to use external antennas to improve the gain as well.

Given this factor, we decided to construct a headset with built-in patch antennas[*16] for receiving satellite broadcasts, along with a Low Noise Amplifier (LNA). **Photo 2** shows the headset with the built-in antenna.

Figure 2 shows an overview of the "MobaHO!" receiver system, which is comprised of built-in antenna systems 1 and 2, LNAs, filters, Radio Frequency (RF) circuits, and an external interface connector. The headset equipped with antennas is connected to the external interface connector. The power to the LNAs built into the headset is supplied from the mobile terminal via a cable.

By building the antennas into this dedicated headset, we achieved a receiver structure where the external antenna can be connected to the mobile terminal without causing any discomfort. As a result, the required input level was improved dramatically, and field tests demonstrated that we were able to achieve the technical performance expected from mobile terminals.

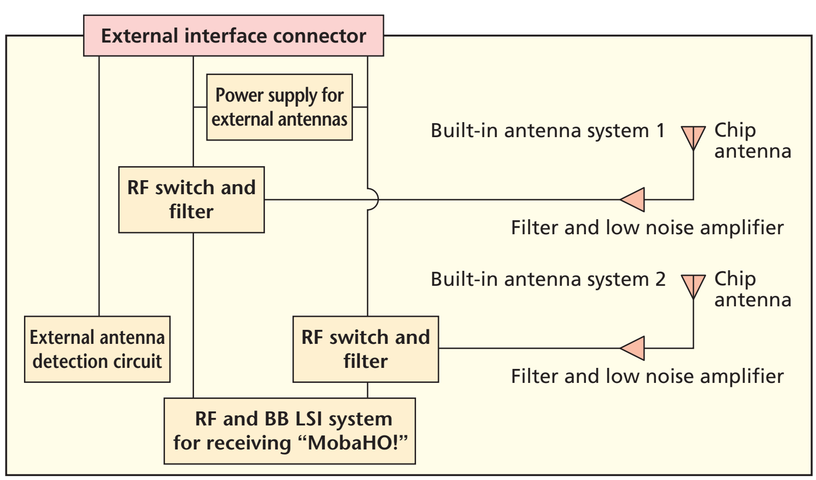
Considering the angle of waves arriving from GF devices and the antenna directivity in the weak electric field of "MobaHO!," the antennas are arranged vertically to the ground surface.

Based on the evaluation results above, we judged that the antennas could be implemented in the mobile terminal.

Photo 2 External view of headset with built-in antennas

3.2 Reception Level Display Function

The D851iWM displays whether the level of broadcast wave reception is outside the range, indicated as weak or strong (3 levels) on the display using pictograms[*17] in the same way as for P901iTV, so that users can easily know the broadcast recep-



BB: Base Band circuit

Figure 2 "MobaHO!" receiver system

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*12 OFDM: A digital modulation method which is known to be robust against multi-path interference. High-speed data rate signals are converted to multiple low-speed narrow-band signals that are transmitted in parallel along the frequency axis. It allows transmission at a high frequency efficiency.

*13 CMOS: A type of semiconductor circuit that conducts very little current in a steady state, resulting in low power consumption.

*14 Helical chip antenna: A type of chip antenna with reduced external size made possible by arranging the antenna elements in a spiral.

*15 Reverse F-type antenna: A type of flat antenna for which the shape of antenna elements looks like a reversed letter F.

*16 Patch antenna: A type of antenna with a flat shape. Although they require more area than linear antennas, they are advantageous in making mobile terminals thinner in that they allow creating thin antenna devices.

tion status at all times. **Figure 3** shows the design of the reception level pictograms.

An analysis of field tests revealed that the reception states could be classified into the following three conditions based on the digital broadcast characteristics.

- A status where the frequency of bit errors in the received stream exceeds the threshold level for data to be decoded normally (Fig. 3 (a))
- A status where bit errors occur sporadically due to a weak electric field, multi-path fading[*18] etc., resulting in possible image and sound disturbance (Fig. 3 (b))
- A status where errors can be adequately corrected and data received normally (Fig. 3 (c))

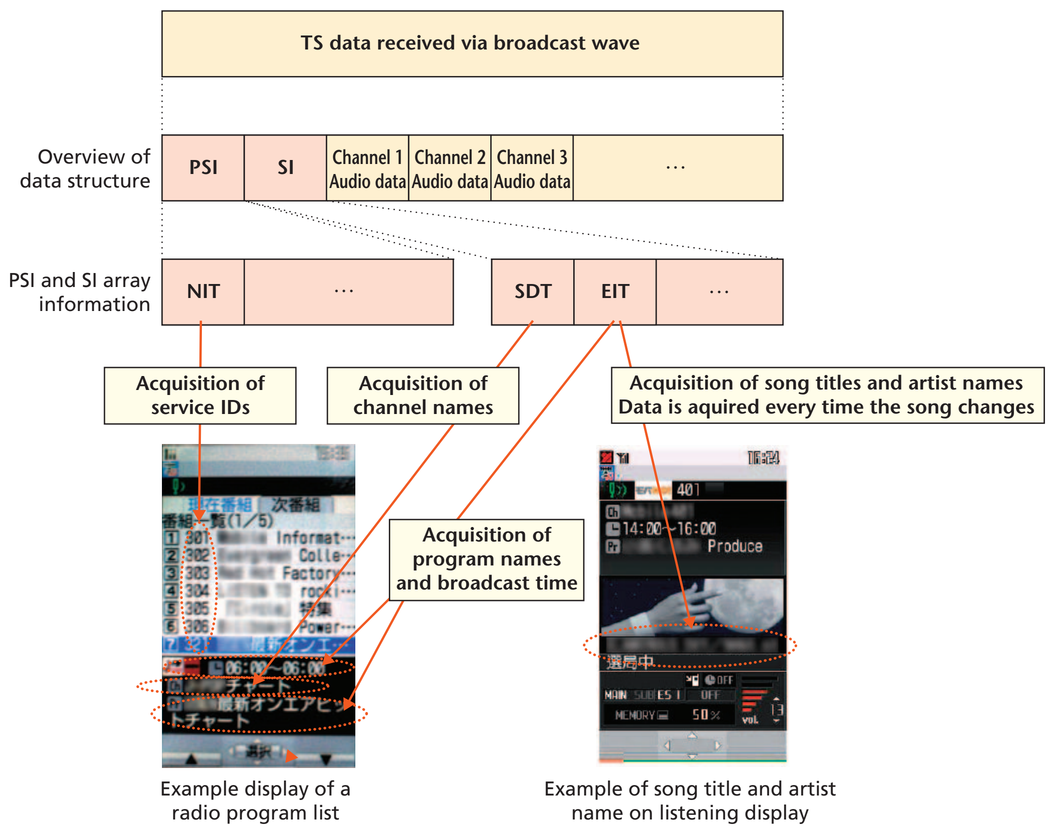
(a) Reception level "Outside Range" (b) Reception level "Weak" (c) Reception level "Strong"

Figure 3 Reception level display pictogram

The three reception levels are displayed based on appropriate threshold value parameters defined according to these states.

3.3 Radio Program Functions

"MobaHO!" provides services through at least 40 channels including video channels and music channels. Data in these



SDT (Service Description Table): Contains channel name and other information related to the applicable channel.
* This function is provided only in Japanese at present.

Figure 4 Overview of radio program functions

*17 Pictogram: Icons and other forms of picture display, rather than letters. Pictograms such as i-mode and antenna symbols are used in DoCoMo's mobile terminals.

*18 Multi-path fading: A phenomenon whereby a radio wave is subjected to repeated reflection and diffraction due to geographical features and buildings, and thus reaches to a receiver as multiple radio waves.

channels is multiplexed on a single broadcast wave and transmitted. We implemented the radio program functions so that the user can view information on the many music channels of "MobaHO!" for easy selection. **Figure 4** shows an overview of the radio program functions. The radio program functions in "MobaHO!" are required to display a list of channel names that can be played on the mobile terminal, program names, broadcast time, and other program information.

In "MobaHO!," Program Specific Information (PSI) and Service Information (SI) are multiplexed on the broadcast wave and transmitted so that a receiver can acquire and play data constituting a specific program transmitted via a single channel selected by the user from among the multiplexed channels on the broadcast wave. PSI mainly consists of control information indicating the relationship between multiplexed signals and program information, and includes a service ID assigned to each channel. SI mainly consists of program information to be provided to users and includes channel names, program names, and program details. In other words, PSI is used to demodulate and play a channel selected from the multiplexed signal, and SI is used as complementary information provided to users.

The radio program functions acquire SI and SPI multiplexed on the broadcast wave, rather than acquiring the information from external sources via communication. The functions then identify service IDs, channel names, program names, and broadcast time schedules from the acquired SI and PSI, and display the information in a list. Information is displayed for the currently broadcast program and the next program. Moreover, the user may select a channel by selecting a desired program from the current radio program.

Moreover, when listening to a chosen program, the titles of songs being broadcast and the names of artists are displayed as needed by acquiring extended event identifiers placed in the SI Event Information Table (EIT)[*19].

With these radio program functions, we made it possible to easily view channel information even though there are many channels from which to choose, thus improving convenience for the user.

3.4 Channel Selection Functions

In order to select a channel with "MobaHO!," the Network Information Table (NIT)[*20] included in PSI is acquired. Then the desired program is acquired by specifying the corresponding service ID from among the information included in the NIT. The following channel selection methods are implemented:

1) Up/down Channel Selection Function

A new channel can be selected by quickly pressing the left/right key of the cross key to increment or decrement the service ID while listening.

2) Direct Channel Selection Function

A channel can be selected by directly specifying a service ID by pressing the numeric keys on the mobile terminal while listening.

3) Last Channel Selection Function

The current channel selected by the user is retained as history data and automatically selected the next time the radio program functions are used, even without having to select a channel.

3.5 Recording Functions

The recording functions record programs while the user listens to "MobaHO!," the terminal is equipped with 1 GB memory that allows about 20 hours of recording. By using a format called Transport Stream (TS)[*21] defined by MPEG-2 when saving content, it is possible to reduce the processing volume as well as the CPU load during recording. The sound processing blocks used by the "MobaHO!" listening function do not change when playing recorded files, thus achieving more efficient implementation. Furthermore, a function to encrypt recorded files is implemented to allow playing recorded files only on the mobile terminal that recorded them and prevent illegal secondary use of recorded files. By storing recorded files on the terminal in encrypted status at all times, the copyright of recorded files is protected and security improved.

Although in principle any algorithm for encrypting recorded files can be used, we chose an algorithm based on the criteria that it should not require large memory capacity for implementation on the terminal, and to allow for high-speed processing.

*19 EIT: Contains the name of a program being listened to, broadcast date/time, program contents, and other information related to programs.

*20 NIT: Multiplexed within TS (see*21); contains information about modulation frequency and other transmission channel information, service format, service ID, etc.

*21 TS: A data stream in which video, sound, and other data belonging to multiple programs are divided into individual packets and sequentially rearranged after adding information to identify programs and other information.

With this approach, we made encrypting/decrypting processing more efficient and managed to reduce the CPU load when recording and playing recorded files.

Note that, for the sake of copyright protection, recorded files cannot be copied, edited or set as ringing tone.

3.6 Power Management Functions

Since listening to “MobaHO!” consumes a significant amount of power, continuous listening will burn out the battery relatively quickly. For this reason, an alarm will notify the user when the battery capacity drops below a specified value to prevent battery depletion without the user being aware of it.

Figure 5 Image of external speaker usage

3.7 External Speaker Connection Function

In order to expand the concept of music mobile terminal further, we implemented a function to output sound played by the “MobaHO!” listening applications as well as music applications of the music player, and FM radio functions for external stereo speakers via a desktop cradle. **Figure 5** shows how this function is used.

A standard φ3.5 stereo mini jack is used for the stereo sound output terminal of the desktop cradle to afford versatility in various external speakers.

Moreover, it is possible to input remote control signals via the same terminal for controlling the music applications of the D851iWM from external devices.

Given these additional functions, the D851iWM can be used as a simple audio device allowing users to enjoy music not only on the go, but also at home.

3.8 “MobaHO!” Online Registration Function

“MobaHO!” is a charged service for which broadcast pro-

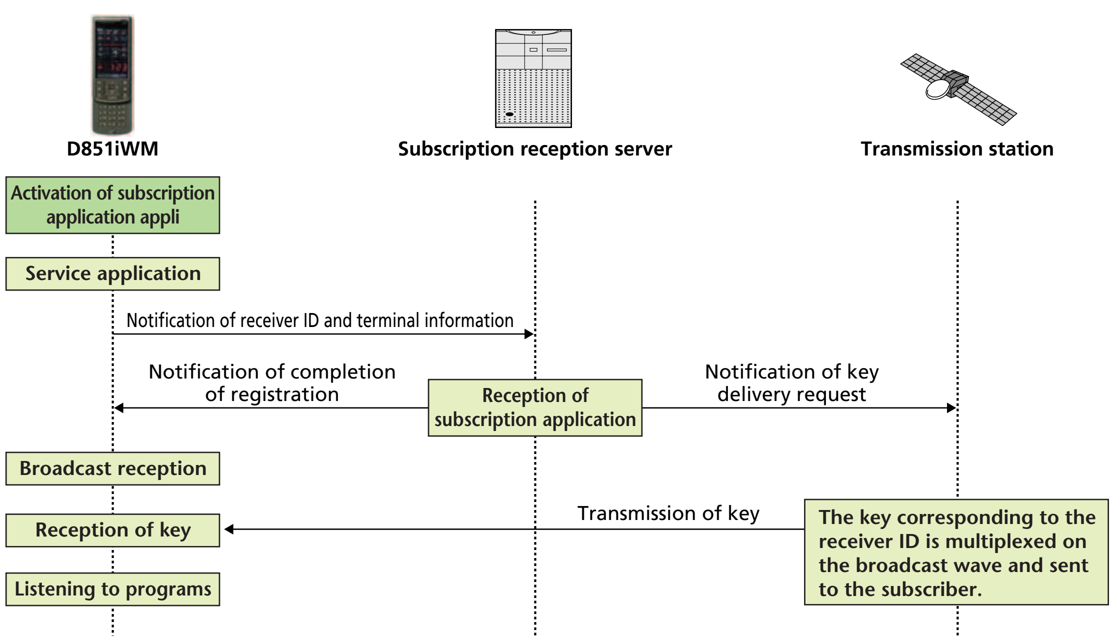


Figure 6 Flow of online subscription application

grams are encrypted. In order to listen to “MobaHO!,” users must inform the receiver ID recorded in the Conditional Access (CA) module[*22] implemented in the mobile terminal to Mobile Broadcasting Corporation for subscribing and obtaining a key for decrypting broadcast programs received via the broadcast wave.

Conventionally, users had to inform their receiver ID to Mobile Broadcasting Corporation via telephone or the Internet, and complete a complicated subscription application procedure. To alleviate this situation, we implemented i-appli that handles the entire subscription application procedure for listening to “MobaHO!.”

Through i-appli, the receiver ID is sent together with the relevant mobile terminal information to a server set up by Mobile Broadcasting Corporation. Once registration on the server is completed, a key is automatically multiplexed on the broadcast wave and transmitted to the mobile terminal, allowing the user to listen to “MobaHO!” (**Figure 6**).

By allowing the user to submit an application and subscribe to the service through this simple i-mode-based procedure, we improved the user convenience.

4. Conclusion

This article described an overview of the “MobaHO!” reception functions and other functions implemented in the D851iWM, a newly developed mobile terminal. In the future, we plan to focus on improving the user interface, reducing size and weight, and researching ways to save power consumption for even longer playing time.

*22 CA module: A module implemented in a receiver for determining whether a broadcast can be received.