New Technology Reports

Hearty Style Terminal Prototypes
—Toward Realization of Mobile Terminals Friendly to Anyone—

Katsuhiro Ohno, Taku Onodera, Masashi Morioka, Yukiya Miyashita and Ichiro Fujisawa

Customer Equipment Development Department is working toward realization of convenient terminals that can be used even by disabled or elderly people to develop "mobile terminals friendly to anyone." As a part of our efforts, we have developed prototypes of receiver-microphones adopting osseous conduction-based speakers that work with hearing aids for people with hearing impairments and communication terminals using graphic symbols for people with mental disabilities.

We developed and evaluated the prototype of communication terminals using graphic symbols in a collaboration project with Shinshu University.

1. Introduction

Mobile terminals have become essential tools for everyone, including disabled people. Recognizing this need, DoCoMo promotes "activities to create warmer relationships between people as well as between customers and DoCoMo, based on the concept of universal designs to pursue products and services friendly to anyone"; these are promoted under the name of Hearty Style. An example of such activities is offering a so-called Hearty discount (partnership discount) for disabled people. The Customer Equipment Development Department has also been developing mobile terminals such as the "Raku Raku" (simplicity) Phone series for a while in pursuit of this concept.

In order to realize mobile terminals that can be used conveniently and comfortably by more customers including disabled people, it is necessary to conduct development taking the specific needs and characteristics of people with various impairments into full consideration, in addition to the efforts that have been made so far.

Impairments can largely be classified into vision impairments, hearing/speech disorders, physical handicaps such as orthopedic impairments, internal disorders, and mental disabilities. **Table 1** shows supporting methods for people with each of these impairments.

This time we focused on hearing impairments and mental disabilities, and developed prototypes of a receiver-microphone adopting loudspeakers using osseous conduction (**Photo 1**) and a mobile terminal adopting graphic symbols for communication (**Photo 2**), respectively, for these two types of impediments.

This article provides an overview of our efforts and explains the receiver-microphone and the mobile terminal adopting graphic symbols for communication we designed in the work reported here.

2. Receiver-Microphone Working with Osseous Conduction and Hearing Aids

The receiver-microphone developed here is a device that supports telephone communication for people that has hearing difficulties with existing mobile terminals. Targets assumed are people with hearing disorders and hearing difficulties with age.

2.1 Problems Involved When People with Hearing Impairments Use Mobile Terminals

There are various types of deafness such as conductive deafness, perceptive deafness, and senile deafness (**Table 2**), but they can largely be classified into "conductive deafness" and "perceptive deafness." People with hearing impairments have difficulties communicating via existing mobile terminals due to insufficient sound volume and other problems. In addition, the majority of people with hearing impairments wear "hearing aids," which makes the communication even more difficult due to the tendency of the radio waves of the mobile terminals, especially Personal Digital Cellular (PDC) terminals, causing noise by radio interference to the hearing aids.

Table 1 Types of impairments and support measures

Type of impairment	Support measure
Vision impairments	Voice Linkage with external devices (Braille keyboard etc.)
Hearing/speech disorders	Osseous conduction Sign language communication Linkage with hearing aid
Orthopedic impairments	Linkage with external devices
Internal disorders	Internal sensor
Mental disability	Use of graphic symbols

Photo 1 Receiver-microphone

Photo 2 Graphic symbol communication mobile terminal

Table 2 Types of hearing impairments

Type	Explanation
Conductive deafness	Deafness due to impediment of organs that transmit sound to ears, external auditory meatus and middle ears
Perceptive deafness	Deafness due to impediment of middle ears and auditory nerves
Mixed deafness	Deafness with characteristics of both conductive and perceptive deafness
Senile deafness	Deafness with age; there are cases of mixed deafness
Others	Occupational, drug-induced (toxic), noise-induced, sudden, functional and other hearing impairments

2.2 Requirements for Mobile Terminals for People with Hearing Impairments

In the prototype analysis phase, we set the following requirements: it must be possible to use together with existing mobile terminals; operation must be easy; the design must be immediately acceptable to elderly people; and it must work together with hearing aids. In addition to these requirements, it was decided that "hearing with an osseous conduction speaker,"

"coordination between receiver-microphone and hearing aid" and "prevention of radio wave interference" would be incorporated as key functions.

2.3 Prototype of Receiver-Microphone for People with Hearing Impairment

We took the ease of use into consideration by adopting a handset-type shape, large operation switches and convex symbols.

1) Osseous Conduction Speaker

When we hear sound, we hear two types: sound conducted through the air is called air conduction sound, and sound conducted via our skeletal structure is called osseous conduction sound (**Figure 1**). An osseous conduction speaker adopts technologies that make use of osseous conduction sound and can be used in conversation and phone calls in noisy environments. Since osseous conduction conveys sound (vibrations) received by the skull to the middle ears, it is expected to be effective for people who suffer from conductive deafness.

Osseous conduction speakers adopts either "piezoelectric" or "electromagnetic" devices. **Table 3** shows a comparison of both types. For the prototype developed this time, we adopted a piezoelectric speaker due to its low power consumption and thin shape taking the fact that it is mounted in the mobile terminal into consideration.

A piezoelectric osseous conduction speaker operates by generating ultrasonic sound vibrations by mechanical resonance by applying voltage to a piezoelectric ceramic (**Figure 2**). By bundling together several piezoelectric ceramics, a piezoelectric actuator is created. A piezoelectric osseous conduction speaker device is made of multiple layers of piezoelectric ceramics.

2) Coordination between Receiver-Microphone and Hearing Aid

Since the majority of people with hearing impairments wear hearing aids, we made sure that the receiver-microphone would work in coordination with hearing aids. A hearing aid is normally equipped with a function to receive sound via an electromagnetic induction coil (T-coil) called "T-mode[*1]" that applies the right-hand rule. When magnetic fields are radiated from electric wires installed in the floor or other surfaces, commonly known as an induction loop system, it becomes possible to receive the electromagnetic energy through the reception coils in the hearing aid. In other words, it becomes possible to hear the sound of the sound source directly from the speakers of the hearing aid, rather than as voice mixed with noise from the microphone of

*1 T-mode: Abbreviation of Telephone mode, the name of a hearing aid function.

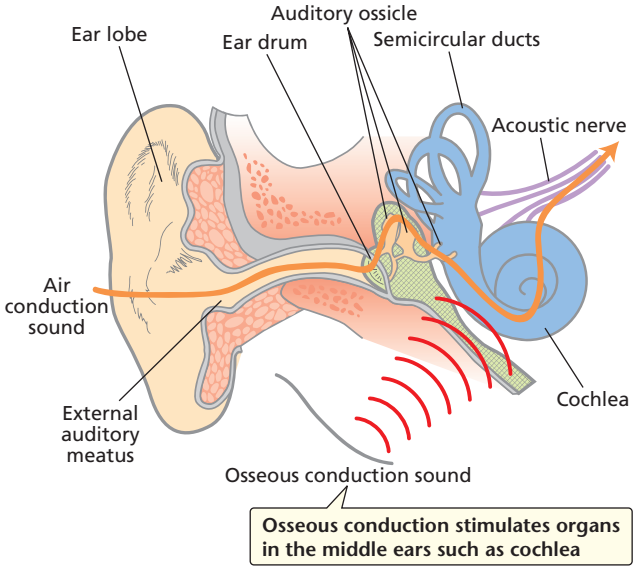

Figure 1 Osseous conduction sound and air conduction sound

Table 3 Comparison between piezoelectric and electromagnetic speakers

	Piezoelectric	Electromagnetic
Generative force	○	×
Displacement accuracy	○	×
Response speed	○	×
Energy efficiency	○	×
Heat generation	○	×
Noise	○	×
Size	○	△
Cost	△	○
Displacement	×	○
Total judgment	◎	△

Generative force: Force required to restrict the displacement of an actuator to 0.
Displacement accuracy: Accuracy of displacement variation that can be guaranteed as a function of voltage for instance.
Displacement: Amount of displacement that can be guaranteed as a function of voltage for instance.

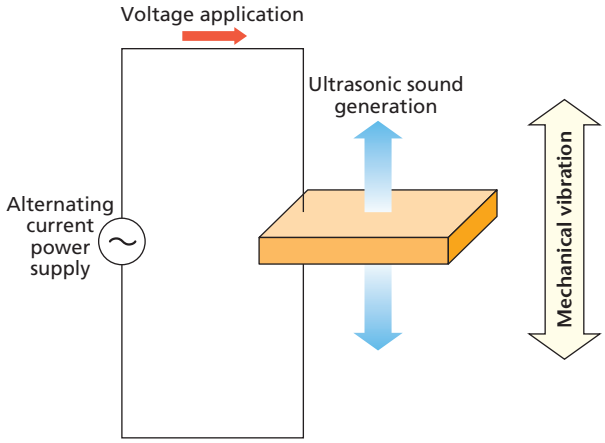

Figure 2 Operation principle of piezoelectric ceramic

the hearing aid.

In order to generate electromagnetic fields, there are methods to install special parts such as coils or use leak magnetic flux from coils of speakers, etc. In the prototype, we adopted a flexible substrate type coil, assuming that such parts should be built into the mobile terminal. Moreover, considering cases where the speaker is used in the T-mode only, we mounted special coils for generating magnetic flux (**Figure 3**). We designed the prototype such that electromagnetic connection was established between the hearing aid and receiver-microphone via the T-coil and connection between the receiver-microphone and mobile terminal was established using Bluetooth[*2].

3) Prevention of Radio Wave Interference

In order to reduce the radio wave interference between a mobile terminal and a hearing aid, it is effective to separate them physically.

There are basically two ways to separate them, by using wired (cable) communication and by using wireless communication. We chose a wireless, Bluetooth-based approach for the purpose of improving ease of use for the prototype. We adopted Bluetooth version 1.2.

We implemented the HeadSet Profile (HSP) for the Bluetooth profile; thus, any mobile terminal with built-in Bluetooth functionality, such as F900iT, can be connected directly. Mobile terminals not equipped with Bluetooth can be connected via a Bluetooth adapter, which is plugged into the ear phone terminal (**Figure 4**).

*2 Bluetooth: A registered trademark of Bluetooth SIG, Inc. in the US.

2.4 Evaluation

We conducted a subjective evaluation monitor test involving 34 people with hearing impairments. As a result, 85% of the subjects responded that radio wave interference in the hearing aids was reduced and 35% of the subjects said that they could hear with the osseous conduction speaker.

3. Mobile Terminal Supporting Communication with Graphic Symbols

We developed a mobile terminal supporting communication with graphic symbols (hereinafter referred to as graphic symbol communication mobile terminal) aiming to make existing mobile terminals easier to use so that they can be used as communication support devices, mainly targeting mentally disabled and/or autistic people (Photo 2).

Graphic symbols refer to icons made from simple illustrations, characters and voice. **Figure 5** shows an example of graphic symbols.

Many of the mentally disabled and/or autistic people are said to have difficulty in understanding language and thus have problems with voice phone calls and communication via e-mail as well. “Picture cards” are sometimes used to communicate between them. Such “picture cards” describe contents illustrations, photos and/or characters. **Photo 3** shows an example of how the concept may be used in practice.

We started the prototype development with the idea of using these “picture cards” in a mobile terminal. Note that this prototype was created in a joint research with Shinshu University and

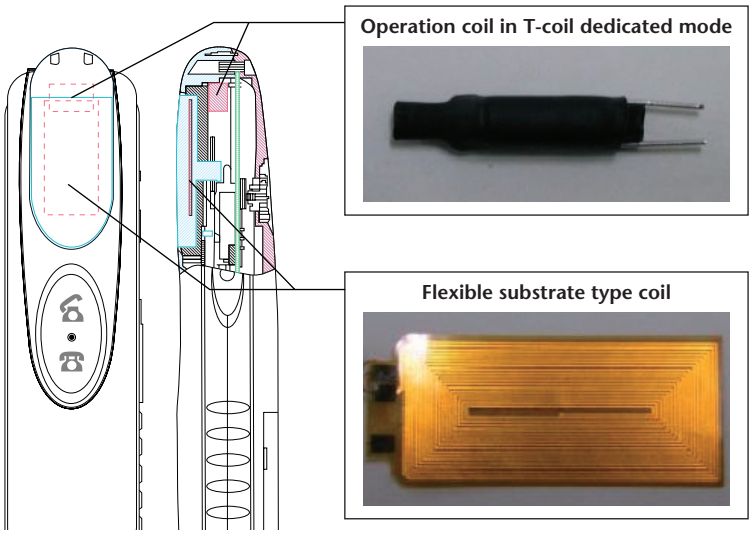

Figure 3 T-coil layout

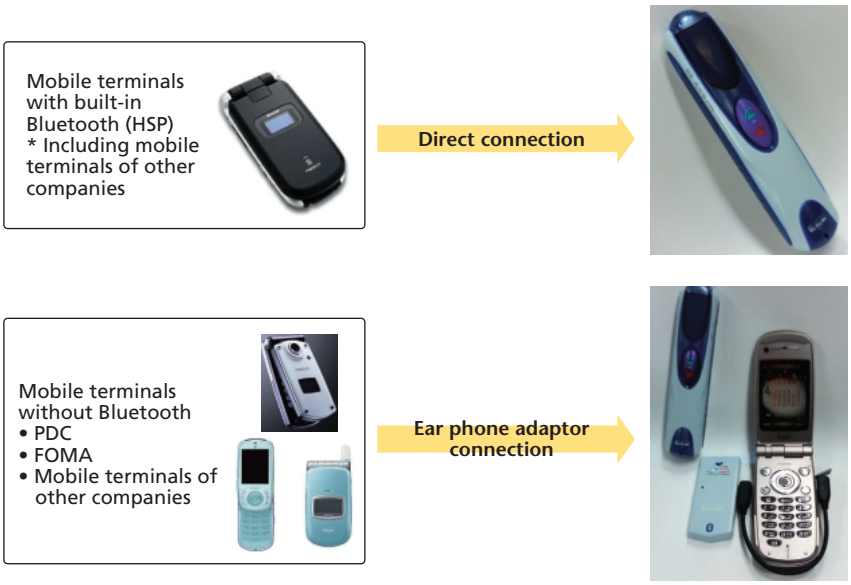

Figure 4 Connection with receiver-microphone

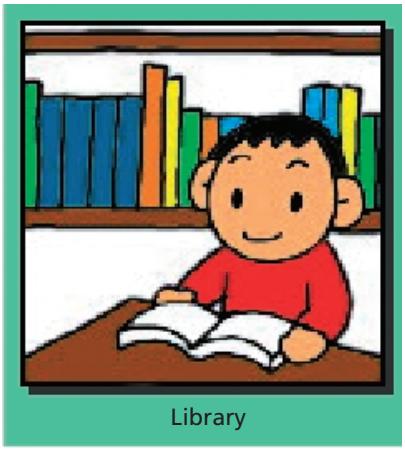

Figure 5 Graphic symbol

Photo 3 Picture card usage example

the development was promoted by dividing the subsequent tasks of specification formulation, graphic symbol creation, mobile terminal development and evaluation between Shinshu University and the Customer Equipment Development Department.

3.1 Problems Involved When Mentally Disabled People Use Mobile Terminals

Mentally disabled and/or autistic people have undeniable problems with certain points in leading their daily lives. The development took its starting point in an analysis of the problematic points involved in using mobile terminals, where we placed ourselves in their shoes. As a result, we narrowed down the points into the following four items.

- Visual character information
- Understanding and managing time intervals
- Complicated tasks as in key operations
- Menu structure of the current mobile terminals

Moreover, it was the wish of many supporters (parents, teachers, etc.) to use mobile terminals, which everyone owns as a communication support device. In particular, they requested Global Positioning System (GPS) functions that would allow the supporters to locate the position of the mentally disabled and/or autistic people in their care in case they get lost, and emergency message functions that the mentally disabled and/or autistic people can operate with a single touch, as well as various other functions.

3.2 Requirements for Mobile Terminals for Mentally Disabled People

Based on the analysis outlined above, we set the following requirements: it must be possible to perform most operations

using only graphic symbols without having to rely on character information; the mobile terminal must support time management, and the schedule function prompting the next action must be easy to understand; the operability must be improved by using a touch panel, such that complicated key operations can be eliminated; the functions must be limited to the minimum, i.e. only the essential functions must be implemented using as few layers of operation as possible; and, finally, the mobile terminal must be a supporting tool that can be customized to each person.

3.3 Prototype of Graphic Symbol Communication Mobile Terminal

Based on these requirements, we implemented the following functions in the prototype mobile terminal.

1) Face-To-Face Communication Function

The mobile terminal is used to convey messages in a direct, face-to-face manner and a graphic symbol can be selected according to their intention. The selected symbol is enlarged in order, and the registered sound is played.

2) e-mail Function

In the same way as for the face-to-face communication function, a selected graphic symbol is used when sending an e-mail. The address is also selected with a graphic symbol from the telephone book. When an e-mail is received by the graphic symbol communication mobile terminal, “an e-mail arrived from XX” message is played, the graphic symbol is enlarged and displayed, and the corresponding sound is played.

3) Telephone Book Function

Registered people are displayed and selected using graphic symbols. Columns for birthdays and memos are added to the registered address columns in order to answer the wish to widen the user’s communication circle by the telephone book.

4) Schedule Management Function

As a time management support, a schedule registration function covering two days and a count-down timer function are installed. It is possible to register up to 15 items a day, and starting and ending times are notified by sound. The count-down timer can be set in five minute intervals. It displays the remaining time with an indicator that is easy to see visually, and sounds are played when the remaining time is down to half and when it runs out.

5) PC Support Tool

Since the degree of disability varies, we prepared customization functions to accommodate the users’ needs in a flexible manner. It is possible to set the telephone book and schedule, create new graphic symbols and edit the graphic symbol library.

6) Others

In addition to the functions above, the prototype terminal is also equipped with log output functions for research purposes, setting functions that allow the user to choose between display or non display graphic symbol text, etc.

3.4 API Implementation to Prototype Terminal

Considering that this technology is likely to be used in many terminals in future, it is desired to be able to add functionality with i-appli and be as independent of the specific model as possible. We thus added three Application Program Interfaces (API) dealing with reading/editing the graphic symbol library, voice input/output for graphic symbols and touch panel functionality, which cannot be performed with the current i-appli.

1) SD File API

In order to handle the large graphic symbol data, the data stored in the graphic symbol library are saved in external memory (miniSD card). An SD File API was added to allow the access to the graphic symbol data from i-appli. Moreover, smooth display switching and reading out received mail were made possible by creating a graphic symbol table at the activation of i-appli.

2) Voice Recorder API

Since many mentally disabled children are primarily familiar with voices of parents and teachers, we added a Voice Recorder API so that voices of parents and teachers can be recorded and associated with new graphic symbols.

3) Pointing Device API

We installed a touch panel to achieve easy operations and implemented a Pointing Device API to support touch panel operations. The prototype terminal is a flex-style terminal that allows the phone calls and taking photos while the terminal is folded. By doing so, we aimed at avoiding operation mistakes and unnecessary confusion by showing only the touch panel display on top and hiding the keys.

4. Conclusion

This article provided an overview of the receiver-microphone and graphic symbol communication mobile terminal prototypes we designed for the purpose of creating mobile termi-

nals friendly to anyone. In the future, we intend to clarify the segregation between the customization functions of the graphic symbol communication prototype terminal, which was one of the issues identified in the function analysis conducted as part of this work, and the customization functions implemented using PC tools, simplifying the classification of graphic symbols and making the hierarchy easier to understand in order to improve the prototypes. We intend to continue our examination and development of attractive functions on commercial terminals as well as examination of various technologies such as utilization of voice recognition.

Lately, discussions related to social responsibilities of companies are picking up steam. From this viewpoint as well, development of mobile terminals taking the socially vulnerable into consideration is important. We intend to continue these efforts step by step, eventually hope to be able to create mobile terminals friendly to anyone, whether or not one has disabilities, without having to specialize them toward certain disabilities.

ABBREVIATIONS

API: Application Program Interface
GPS: Global Positioning System
HSP: HeadSet Profile
PDC: Personal Digital Cellular