Wireless Communication-based Safety Alarm Equipment for Trackside Worker

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1. Introduction

According to results of the analysis on present condition of railway accidents in Korea, about 50% of them are recorded as railway casualties based on the number of incidence in railway accident, and if converted into the equivalent fatality index(1 fatality = 10 seriously injured persons = 200 slightly injured persons), the equivalent fatality index caused by casualties occupies 94% of the equivalent fatality index for total railway accidents[1]. These railway casualties are consisted of the casualties by railway transportation and the casualties by railway safety. Casualties by railway transportation refer to the accidents where casualties occur to the passengers, crews, workers, etc. by railway vehicles, and the casualties by railway safety mean the accidents where casualties occur to the passengers, crews, workers, etc. by railway facilities without any direct rear-end collision or contact with railway vehicles. That is, accidents such as the falling down or misstep at platform, electric shock, getting jammed to vehicle doors, etc. correspond to casualties by railway safety. Many measures are being studied to prevent and reduce casualties by railway transportation in such a way that casualties by railway transportation are analyzed to have occupied about 87% among casualties which occupy more than 90% of the equivalent fatality index for total railway accidents, etc.[2-7]. As explained previously, in case of the public casualties by railway transportation which occupy most of the railway accidents, since screen doors were installed or are under progress at almost all of the station buildings for metropolitan transit, they play epoch-making roles in the reduction of casualties. However, studies on safety equipment to protect trackside workers who are employees as target persons of casualties have seldom accomplished yet.
When doing maintenance works for the track or signaling equipment at the trackside of railway, the method which delivers information on approaching of train to maintenance workers through alarm devices such as the flag or indication light, etc., if they recognize the approach of train, is being used by locating persons in charge of safety alarm in addition to the maintenance workers at fixed distances in the front and rear of the workplace. Workers maintaining at the trackside may collide with the train since they cannot recognize the approach of train although it approaches to the vicinity of maintenance workplace because of the sensory block phenomenon occurred due to their long hours of continued monotonous maintenance work. And in case of the metropolitan transit section, when doing the maintenance work at night for track facilities, clash or rear-end collision accidents

between many maintenance trainses called motor-cars can be occurred since there are cases where the signal systems for safe operation of motor-car such as track circuit etc. are blocked or not operated normally. Since the motor-car driver is not able to accurately locate the points where maintenance works and other motor-cars are done, accidents can occur at any times. In other words, workers are exposed to the accident risks when they are performing maintenance works at tracks, because they are sometimes unable to recognize the approaching motor-cars[8].

To reduce these casualty accidents of maintenance workers working at the trackside of and the clash or rear-end collision accidents between motor-cars, we developed safety alarm equipment preventing the accidents by transmitting specific RF-based communicaiton signals from the motor-car periodically and by making the terminal equipment being carried by workers at the trackside provide various alarm signals such as vibration, sound, LED, etc. to workers through receiving wireless signals from terminal equipment of approaching motor-car. Further, the safety equipment held by the maintenance personnel sends signals telling the location of personnel to motor-cars, allowing motor-car driver to know exactly where maintenance personnel work. Such interactive wireless communication links may contribute to reduction of motor-car accidents[9-11]. In addition, if more than two motor-cars are operated, we made it possible to alarm that another motor-car is approaching through bidirectional wireless communications even between the on-board equipment of motor-cars[12][13].

Fig. 1. Configuration of proposed safety equipment

Figure 1 is the one showing an configuration of safety alarm equipment to secure the safety through bidirectional detection between the motor-car and trackside worker proposed in this thesis, and it is the safety equipment making workers evacuate by providing various forms of alarm sounds through recognition of the approaching motor-car by worker's safety equipment if the motor-car approaches within the some distance of front, and on the contrary, inducing to drive carefully by making it possible to check even in the motor-car also if there is any worker existed in the front or not. This is to induce careful driving by providing a motor-car driver with the information also so that the driver can check if there is any work conducted by worker within the fixed distance of front or not, and the alarm signal at the on-board equipment was made to be expressed by LED and alarm sound.

2. Wireless communication-based safety equipment

2.1 Structure of safety equipment using the wireless communication

We designed the safety equipment transmitting alarm signals bidirectionally by using the wireless communication to reduce casualties of trackside workers. Designed safety equipment is consisted of the on-board equipment and the portable device for worker, and it is the safety equipment to reduce casualties by enabling careful driving and evacuation to the safe area by making information on approaching motor-car in the front or information on workers output in the form of various alarm signals respectively. Basic mechanism of the designed safety equipment is made of the structure which makes the signal in a specific frequency band transmitted periodically from the motor-car, and delivers alarm signals in the form of buzzer, LED and vibration, etc. by receiving periodic signals coming from the motor-car to the safety equipment carried by the trackside worker working within a fixed distance in the front. If any worker recognizes alarm signals to alert an approaching motor-car from the safety equipment carried by the worker, the worker will evacuate to the safe area and the alarm sounds can be cutoff. On the contrary, it was developed to make bidirectional communications possible so that whether there is any worker existed in the front or not can be checked from the on-board also[14][15].

Figure 2 is the one showing the configuration of on-board terminal of safe alarm equipment, and it is consisted of RF module to send and receive RF signals periodically, MCU module handling the occurrence of periodic RF signal and operation mechanism of alarm signal, LED module for the output of alarm signal by the light, LCD module to display the information, AMP and speaker parts for the output of alarm signal by the sound, and the power supply module for the input of power supply from a motor-car. Power supply module was made to be input from 5V to 40V so that the power supply of various motor-cars can be input. The frequency band of wireless signal used in this prototype was 424 MHz which is the ISM band. The alarm signal by LED was made to be displayed in different color respectively in accordance with that whether there is any worker existed in the front or another motor-car existed in the front. The alarm sound was made to be adjusted by the motor-car driver, and the LCD panel was made so that the unique number of approached worker's terminal or terminal of another motor-car can be displayed. If wireless signals are being fed back by various terminals within an approaching section, the ID number of terminal was made to be expressed successively in the order of wireless signal feedback. The output of wireless signal of the motor-car terminal of motor-car and that for worker is in the ISM band, and it was adjusted within 10 mW so that the radio wave range can be about 250~300m to suit for the metropolitan rapid transit.

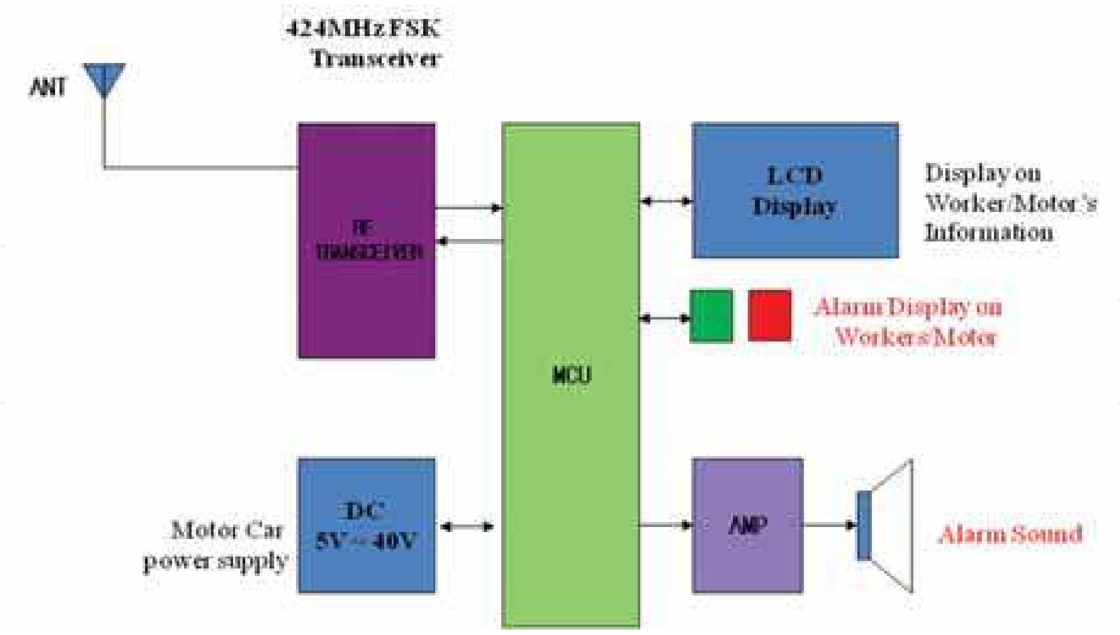


Fig. 2. Configuration of the on-board terminal

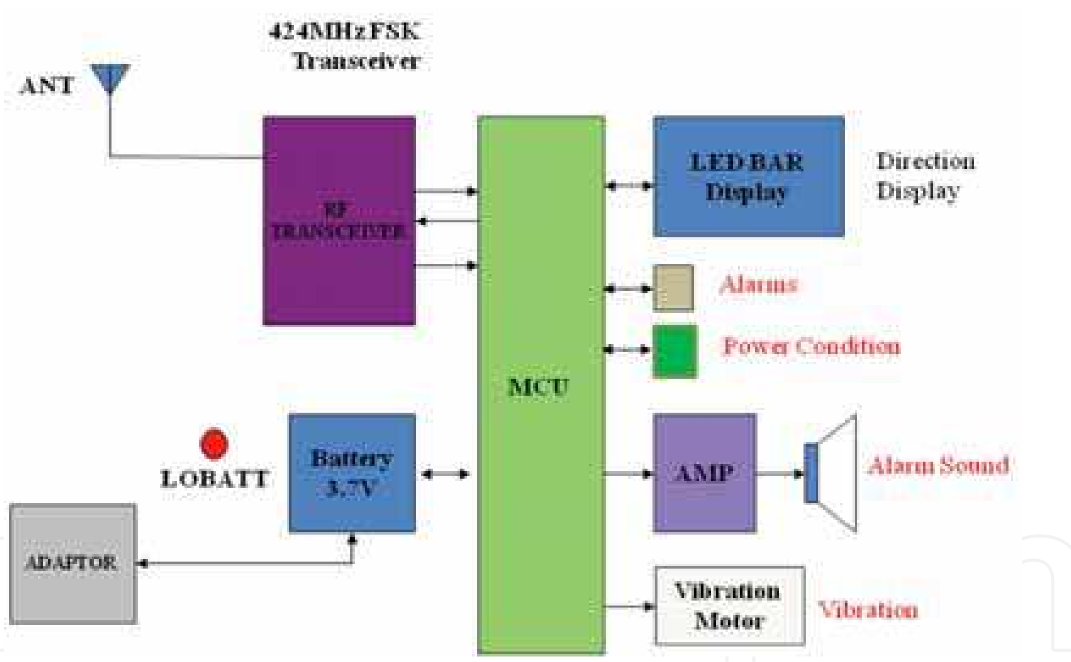


Fig. 3. Configuration of the worker terminal

Figure 3 is the one showing the configuration of terminal for worker and, although its basic configuration is the same as that for on-board terminal in Fig. 2, there is a difference in output part and power supply part of alarm signal. Different from that for on-board terminal, the alarm signal of terminal for worker enhanced its transmission function of alarm signal to the worker through adding an alarm signal by vibration in addition to the alarm signal by LED and sound. Therefore, the vibration motor part was added to the terminal for worker, and the LED alarm was consisted of two kinds of LED displaying the approaching direction of motor-car and the general high brightness LED. In case of the power supply part, although on-board terminal uses power supply inside of the motor-car directly, in case of that for worker, it was made to use batteries after charging them from outside since it is portable, and if the battery charging time is less than three hours, we made the alarm light of 'LOBATT' LED operated. In addition, we made its structure possible to be attached to the worker's waist or put around neck so that it is convenient for the worker to carry with. Table 1 is the one organizing main specifications of the terminal for worker and that for on-board explained previously.

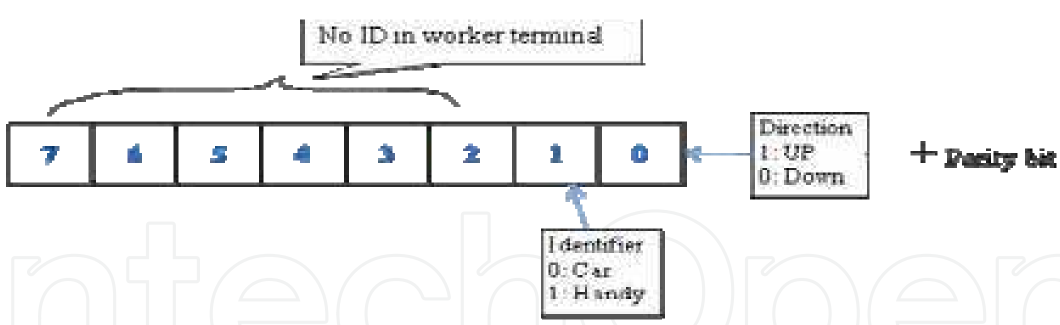
On-board terminal	Frequency	424Mhz
	Output	Within 10mW
	Strength of receipt	-110dbm
	Antenna	External antenna (150mm)
	Input voltage	12V~40V
	Battery	Power supply for motor-car
	Size	190mmx130mmx50mm
	Modulation	F(G)1D/F(G)2D
	Frequency Deviation	±5 kHz
	Bandwidth	8.5 kHz
	Tx Deviation	5 kHz
	S/N Ration	50 dBm
Terminal for worker	Frequency	424Mhz
	Output	Within 10mW
	Strength of receipt	-110dbm
	Antenna	External antenna (50mm)
	Input voltage	3.3~4.2V
	Battery	Storage battery (rechargeable)
	Size	50mmx90mmx25mm
	Modulation	F(G)1D/F(G)2D
	Frequency Deviation	±5 kHz
	Bandwidth	8.5 kHz
	Tx Deviation	5 kHz
	S/N Ration	50 dBm

Table 1. Main Specification of Developed Equipment

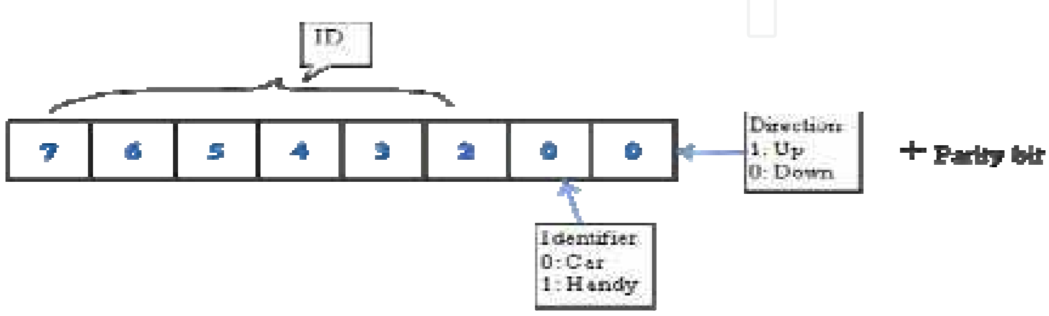
2.2 Structure of the transmission frame between on-board and worker terminals

As explained in the previous section, the safety equipment to protect trackside workers is consisted of the on-board equipment to be installed at the motor-car for maintenance work and the worker terminal to be carried by the worker, and the safety mechanism is operated through wireless communicaiton between these two terminals. That is, if the first motor-car in advance approaches the trackside worker, portable worker terminal receive the signal from onboard equipments and indicate warning. If the worker recognizes a warning signal from his alarm terminal, it cut off the alert sounds through "stop key" activity. And then, in case the other motor-car approaches the worker in a row, it must show alert sound notifying the access of the second motor-car regardless of the "stop key" activity which is resulted from the recognition of the access of the first motor-car. For this reason, the transmitted frame architecture is designed such as Fig. 4 (a) to transmit the ID information of the motor-car to trackside worker terminal together with the warning indication. It can assign ID of the 64 motor-cars like transmitted frame in the figure. In case it needs to assign more than 64 motor-car's ID, it is possible if it sets up the transmission frame to 2 bits. We also added the information of the proceed direction of the motor-car as we verified in this frame. Because there are only two directions, which are upward and downward, we send this information with transmission frame and display the worker to show which direction the motor-car is approaching in classifying the LED color and displaying them. Figure 4(b) shows the structure of the transmitted frame which sends from portable equipments for workers to onboard terminal. It is not assigned the ID number because it is unnecessary to classify the rail workers in onboard unlike (a).

As explained previously, the safety equipment for on-board and for worker has several operation switches such as the power supply switch, mode conversion switch, etc. In case of the power supply switch, if this is the case of safety equipment for motor-car, the power supply switch for motor-car was not added separately so that it could not transmit wireless signals to the front periodically and continuously and the driver could not turn off the output signal arbitrary when the power supply of motor-car was input. Checkup button is the button added to enable buzzer sounds cut off if the worker recognizes the approach of motor-car. When making this button operated, it was designed so that the buzzer sound could be operated again if any new wireless signal was received from another approaching motor-car, although the buzzer sound was not expressed if any wireless signal from currently approaching motor-car was received.



(a) Structure of the transmission frame for on-board terminal ➔ Worker terminale



(b) Structure of the transmission frame for worker terminal ➔ On-board terminal

Fig. 4. Transmitted frame between worker and on-board terminal

2.3 Operation mechanism of the alarm signal

Since the motor-car terminal or worker one have the same wireless aignal transmission distance respectively, the alarm of the motor-car and worker terminals will be expressed if the motor-car approaches within the wave transmission distance on the basis of worker. Then, if the worker recognizes this alarm, he/she will push an alarm stop button and the expression of alarm signal at the terminals for worker and motor-car will be stopped accordingly.

Figure 5 is the figure explaining this basic alarm operation mechanism. That is, if the motor-car #01 enters within the wave transmission area of worker terminal, the worker terminal will receive RF signals coming from the motor-car #01 terminal and make alarm signal occurred. And right away, it makes drive carefully by making the alarm informing that there is a worker in the front occurred at the terminal of motor-car #01 by feeding back to the terminal of motor-car #01. The trackside worker will evacuate if he/she acknowledges an alarm signal of worker's terminal, and afterwards since continued alarm signal is not required to be occurred, the alarm signal at the terminal for worker and for motor-car is made to be stopped by handling the checkup button in the terminal for worker. At this time also, although the terminal of motor-car #01 transmits RF signal periodically and the terminal for worker also receives the signal of motor-car #01 periodically, it was made that the alarm signal was not output if an alarm checkup button was pushed. Since then, if the motor-car #02 approaches within the wave transmission area as shown in the figure, it is implemented as a mechanism where the worker's terminal makes alarm signal occurred again like Fig. 5 and at the same time makes alarm signal occurred at the motor-car #02 by feeding it back to the on-board terminal.

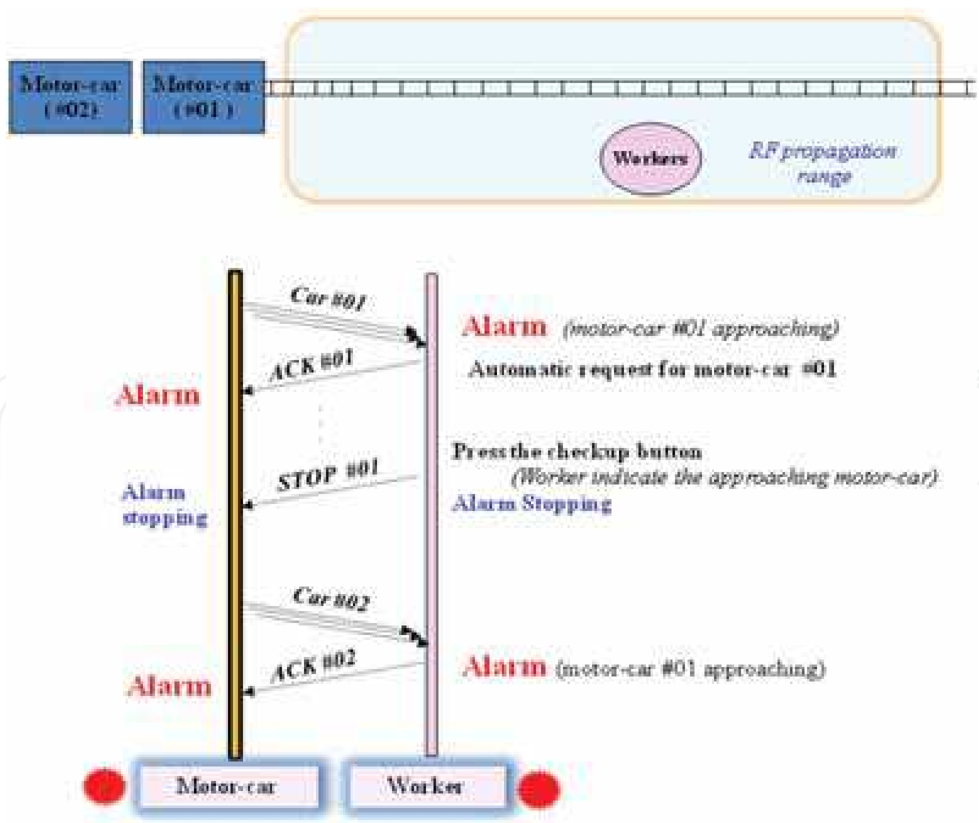


Fig. 5. Basic alarm operation mechanism

In addition to the basic alarm operation mechanism like Fig. 5, certain situation where one motor-car entered within the wave transmission area and then entered again after having left it can be occurred. Since this is the operation of motor-car to be used for works for the trackside maintenance not as a generally operated motor-car, it is possible to repeat frequent forward and backward driving in a narrow area. This case is the one like Fig. 6, and at this time, the terminal for worker will be stopped if it does not receive any RF signal, and the alarm signal of on-board terminal will be stopped also if it does not receive any feedback signal from the terminal for worker. Since then, when the motor-car #01 newly enters within the wave transmission area, it was made to express alarm signals in the same mechanism as that expressed at the time of first entrance. Unlike the basic mechanism like Fig. 5, this is the mechanism making alarm signals operated from the beginning newly if any RF signal is received again after being disconnected although the signal of on-board terminal with same ID is received.

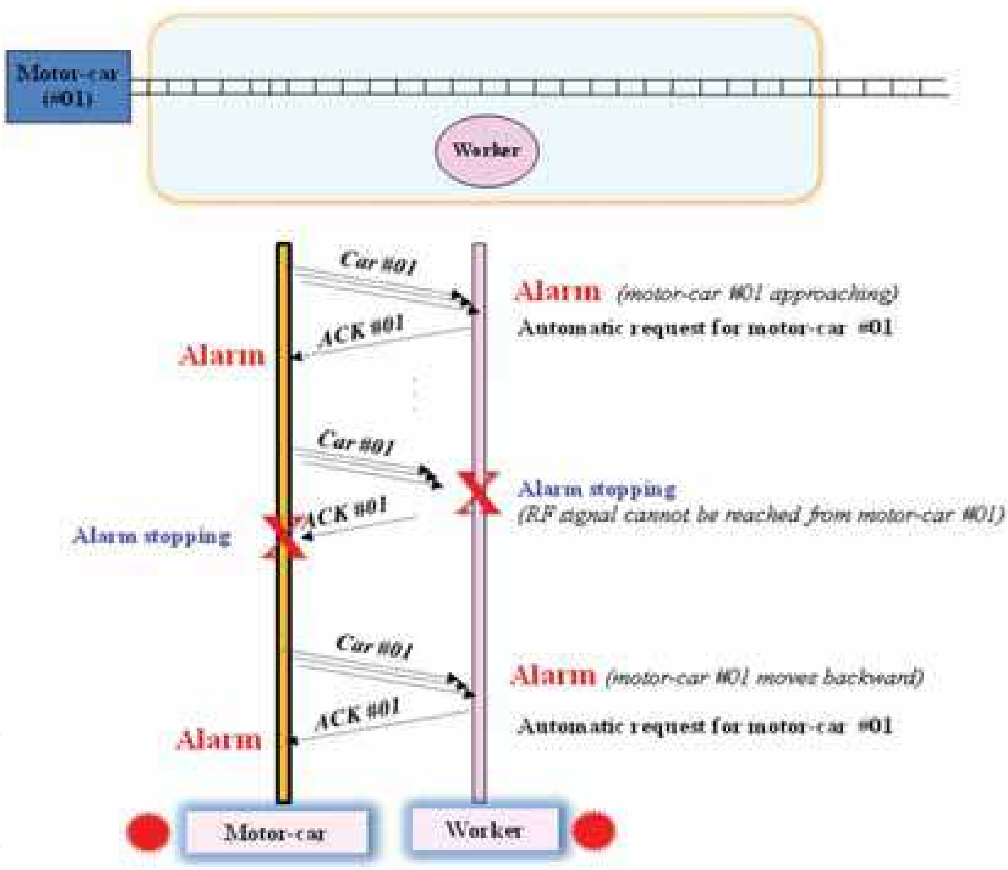


Fig. 6. Alarm mechanism when the motor-car moves backward after leaving its propagation area

Although Fig. 6 is the case where the motor-car enters again after going out of the wave transmission area, there is a case where the motor-car, which is the trackside maintenance motor-car, is operated forward and backward to work within the short area due to its characteristics. This situation is the case where the corresponding motor-car approaches to the worker again by moving backward again within the wave transmission area after the check button is pushed by the worker to stop the alarm after that worker recognizes the approaching motor-car first. That is, in this situation, if the worker terminal does not output the alarm signal again, the clash and rear-end collision accident with motor-car can be occurred again. Thus, the alarm operation mechanism is necessary to solve this problem. Figuer 7 is the one explaining a mechanism to cope with this situation, and the situation mentioned previously was solved by making the alarm signal occurred again if the signal was received from the same motor-car ID after passing a setting time following that the check button was pushed by the worker. The setting time of worker terminal can be varied in accordance with the characteristics of motor-car operation of the railway operation agency, and in the prototype for this study, it was set to 2 minutes by reflecting opinions of motor-car driver and site maintenance worker of Korea.

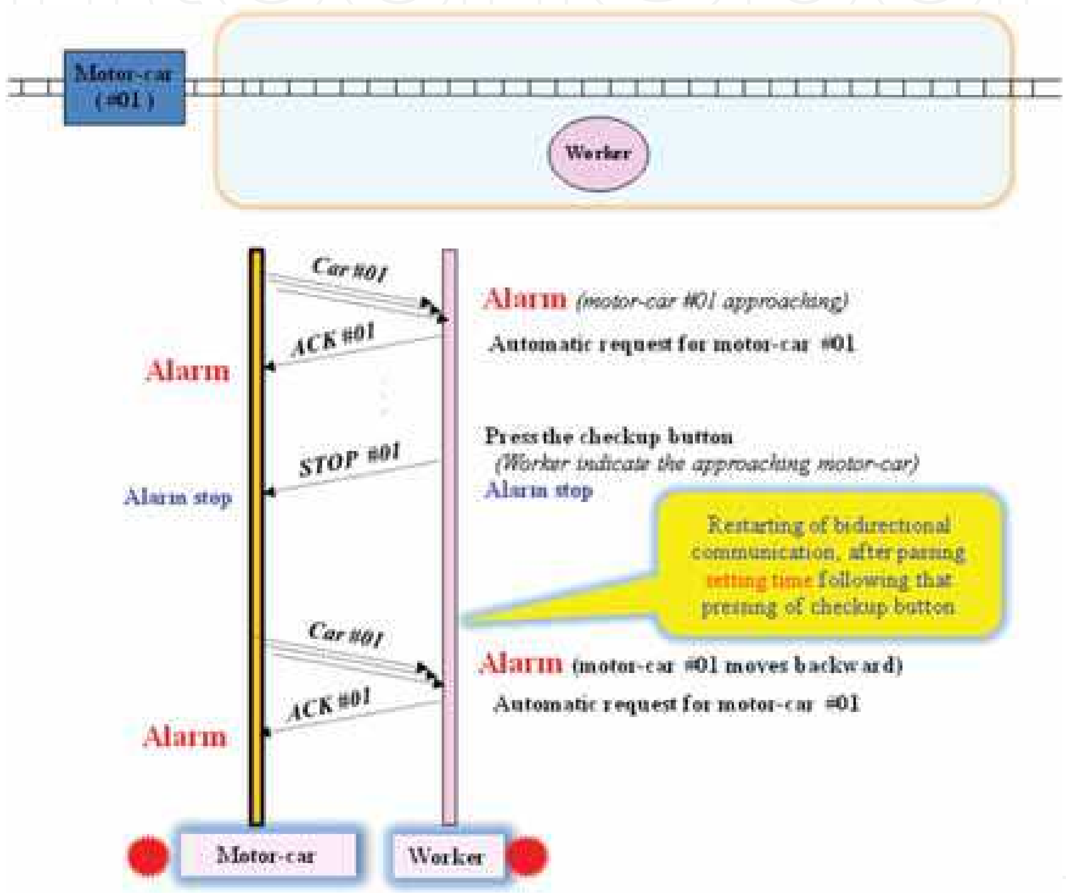


Fig. 7. Alarm mechanism when the motor-car moves backward within the wave transmission area

Actually, motor-cars are being operated for the maintenance of trackside facilities of railway in many railway fields such as the signal, communications, electricity, facility, etc. Generally in case of the railway, the moving location of motor-car can be checked by railway signaling system when the motor-car moves, and accordingly, the control system preventing any clash and rear-end collision between motor-cars by transmitting deceleration and stop signals to the front and rear motor-cars. However, in case of the motor-car, it is impossible to grasp the operation location of motor-car by this signaling system on a real-time basis since it is consisted of a single car or two cars only. Accordingly, it is impossible to check the operation location each other by the system even between the motor-cars, and the operation location each other must be checked by motor-car drivers visually. In addition, because it is impossible to check the location of other motor-cars by eyesights of drivers since operation of these motor-cars are usually accomplished at night, the clash and rear-end collision accidents between each other motor-cars are being frequently occurred currently.

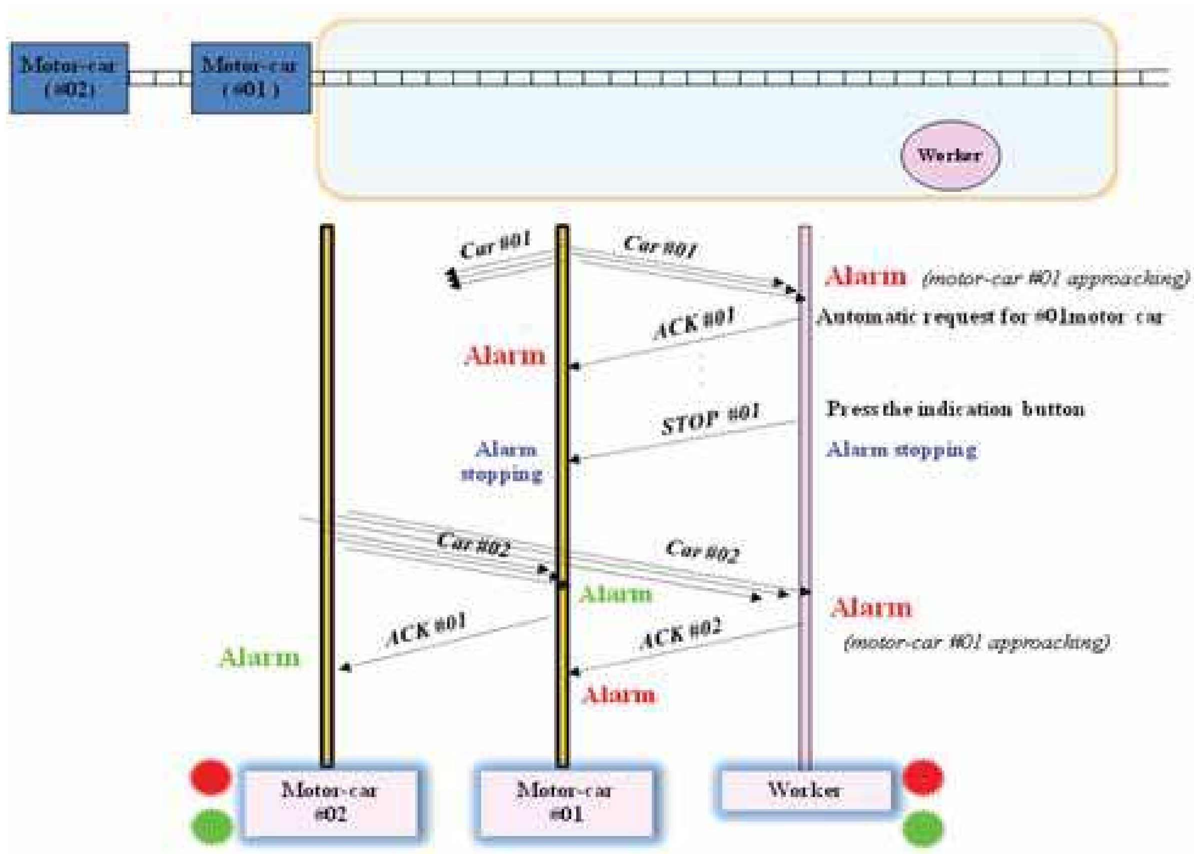


Fig. 8. Alarm operation mechanism the motor-car↔worker and between motor-scars

Figure 8 is the one explaining the mechanism added to prevent clash and rear-end collision accidents between each other motor-cars by making alarm signals occurred in accordance with the approach of each other motor-cars. Although an alarm operation mechanism between the motor-car #01 and the worker is operated in the same manner as several cases explained previously, it is the figure explaining an alarm operation mechanism between each other motor-cars additionally. As shown in the figure, alarm signals between each other will be occurred if the motor-car #01 is approaching to the worker, and the alarm will be stopped by pushing the check button. However, as shown in the figure, the worker terminal makes alarm signals occurred also if the motor-car #02 approaches within the wave transmission area of worker consecutively while moving close to the motor-car #01, and if the motor-car #1 receives a RF signal from the motor-car #02, it makes alarm signals occurred as shown in the figure and makes alarms occurred at the on-board terminal of motor-car #02 by making them fed back to the terminal of motor-car #02. In this case, it was made to have drivers induce safe driving accordingly by making the on-board terminal express alarm signals differently in accordance with whether it is the alarm caused by the worker or by another motor-car. In this prototype, the expression of alarm signal was made to express LED colors differently to classify its recognition on the worker from that on the motor-car.

3. Development and performance testing

3.1 Development of the safety equipment

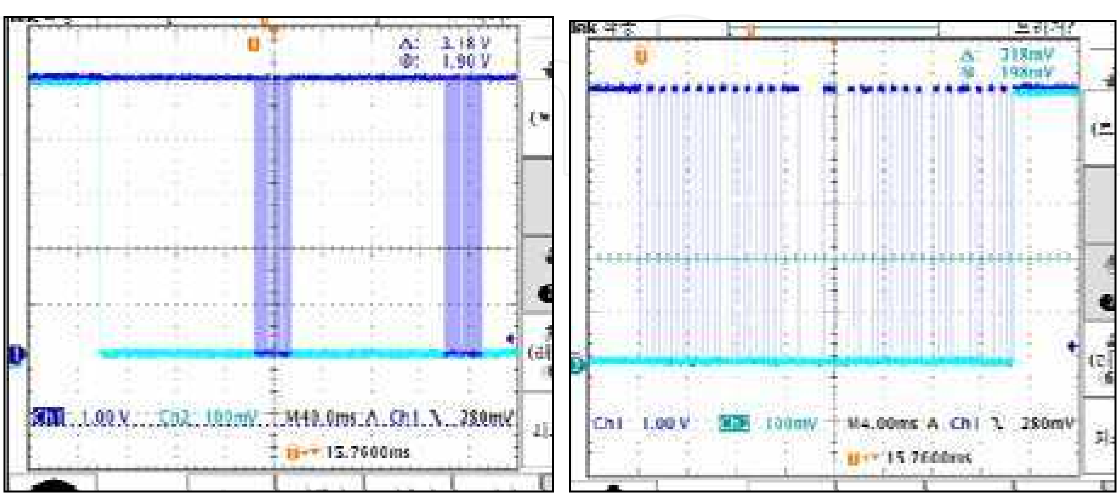
Safety equipment was manufactured and the test was performed at the railway operation site on the basis of the content designed previously. Figure 9 is the worker terminal of prototype developed through this study, and the Fig. 10 is the picture of terminal for motor-car. In case of the worker terminal, it was made so that the adjacent worker as well as the worker himself/herself can check alarm signals by making alarms output so that the red LED and high-luminance green LED can be turned ON if it receives an approach signal from the motor-car. In addition, we enabled alarm signals to be output in a sound too, and at the same time, we made alarm signals output in various forms such that the vibration is occurred at whole parts of the terminal by operating a vibration motor, etc. Output of the vibration alarm is the same form as that for vibration state of cellular phone. It was manufactured in a slightly smaller size than that of cellular phone so that the worker could carry it conveniently, and it could be attached at the waist of worker or an accessory possible to be hung in the neck through necklace could be attached additionally. By using high-capacity rechargeable batteries, the power supply of worker terminal was made so that the worker could use it conveniently.

Fig. 9. Prototype of the worker terminal

As for the terminal for motor-car, an alarm LED which will be output in two kinds of color so that whether an adjacent terminal is for the worker or for the motor-car can be distinguished, a setup display button to set the operational direction of corresponding motor-car and the direction display LED according to it, a lever possible to adjust the size of alarm sound, and the check button to stop alarm signals were attached at the front of the terminal. In addition, by attaching a LCD display device, we enabled this LCD display window to be used if the driver of motor-car wanted to obtain more detailed information by making an operation status of his/her own terminal, an unique number, etc. of the terminal for adjacent worker or other motor-car displayed. Unlike the terminal for worker, the output of alarm was limited to LED lights and alarm sounds only without any vibration. Power supply of the motor-car was used as that of the terminal for motor-car, and the power supply of motor-car was used so that the natural role of terminal as the safety equipment could be performed, and we made that the power supply of this safety equipment must be applied during the motor-car operation since no separate power supply switch was designed. This is to prevent the case fundamentally where the driver turns off the power supply of on-board terminal arbitrarily and makes it impossible to be operated as safety equipment.

Fig. 10. Prototype of the motor-car terminal

Figure 11 is the one showing the waveform of signal to be output from the on-board equipment, (a) is the waveform transmitting signals periodically, and (b) is the one showing an output waveform transmitting the transmission frame like Fig. 4. This output signal from on-board equipment outputs various alarm signals by decoding these transmission signals if the portable device for worker receives them within a fixed distance.



(a) Periodic output waveform (b) Output signal

Fig. 11. Output signal of the on-board safety terminal

(a) On-board terminal installed diverse location

(b) Driving of motor-car with on-board terminal

Fig. 12. Picture of the field test for on-board safety alarm equipment

3.2 Installation and operation as an example at the railway site

For the performance test of developed prototype, we carried out several times of field tests at the track of Seoul Metro, and the functional test to check whether the safety equipment for worker expresses alarm sounds in a form of vibration, buzzer and LED by receiving periodic RF signals from the on-board equipment normally, and whether the mode conversion switch or moving direction of motor-car is expressed normally were carried out in the field test. In addition, the wave transmission distance between the on-board equipment and the equipment for worker was measured to be about 230 ~ 270 m through this field test, and it was verified that this wave transmission distance had satisfied the requirement of this safety equipment. As for test fields, tests were carried out in accordance with various conditions of those fields such as the underground section, ground section and platform section, etc., and especially, we carried out the test in the section where radius of curvature was 150R for wave transmission distance and performance tests.

Figure 12 is showing the pictures of the installation and operation of manufactured on-board equipment, and like those pictures, it was installed in various ways in accordance with the condition of driver's cab of the motor-car such as the front or side of the driver's control panel or the position at driver's head, etc. since there are various kinds of Korean motor-cars. Figure 13 is the picture of field test through worker terminal, and as can be checked in the figure, the approach of motor-car can be easily checked by the worker himself/herself or a colleague near him/her due to the very bright LED light at the time of its approach. In addition, as shown in the figure, it was manufactured in a small size so that the worker can carry it conveniently, and at the same time, an attaching accessory was added so that it can be attached at the waist belt.

Fig. 13. Picture of the field test for worker terminal

As for the field test, tests were carried out in various railway operation environments such as the platform section, underground tunnel track section, ground track section, etc. As a result of field test in the underground section, the alarm expression mechanism tested in the ground was expressed sufficiently and the minimum wave transmission distance being operated normally was measured to be about 230m. Wave transmission distance of about 230m is the most ideal distance required by the metropolitan rapid transit operating agency, and it was verified that the wave transmission distance of prototype had satisfied the required performance through field tests.
We found optimum output of the on-board and worker's antennae through several tests at the railway sites, and fixed a setup time(2 minutes) of worker terminal. After passing through these field tests, 10 sets of the on-board equipment developed through this study are installed and operated currently as an example in the 4 formation of Seoul Metro motor-cars in Korea. Since lengths of some motor-cars are more than 100m, there are some cases where each of the on-board equipment was installed at the front and rear respectively in case of these motor-cars, and some of the motor-cars have only one on-board equipment per each motor-car also. We are supposed to validate the performance and utility of the developed safety equipment through these actual model operations via this actual railway operation agency, and are planning to make maintenance workers at the trackside site of railway check the utility of this safety equipment.

Fig. 14. Motor-car having a long length where 2 sets of on-board equipment were installed

4. Utilization of the developed safety equipment in the other form

The prototype of safety helmet in this section is the safety equipment to reduce casualties where trackside maintenance workers collide with the motor-car since they did not recognize the approaching motor-car, and whose purpose of utilization is the same as that explained in the previous section. Although its mechanism of transmitting/receiving sides, where wireless signals are transmitted from the approaching motor-car periodically and the safety equipment of worker informs the worker of the alarm on approaching motor-car after receiving them, is the same as that explained in the previous section, but it is different in that the form of safety equipment for worker is the safety helmet using the bone conduction speaker[16-18]. That is, it shows the possibility of utilization in various other forms of safety equipment proposed by the authors by applying the form of safety equipment for worker only to the safety helmet to be worn by the maintenance worker while using the configuration of transmitting/receiving sides developed already in the previous section.

Especially, it is the safety equipment which makes workers evacuate safely by informing them of the alarm to approaching motor-car through bone conduction speaker attached at the safety helmet of trackside maintenance worker not in the general method of alarm expression. Of course, it is identical to the basic operation of safety equipment mentioned in the previous section in that this is the safety equipment to reduce casualties in accordance with the bidirectional RF link by which even the driver of motor-car can check the location of worker by transmitting the location of worker from the safety helmet of maintenance worker to the motor-car. Bone conduction speaker attached at the safety helmet in this section has the characteristics to hear sounds through vibration of the skull, and it was not difficult to prove its utilization because the bone conduction speaker using this principle was commercialized already.

Bone conduction speaker refers to the hearing through vibration of the skull, and the bone conduction speaker using this principle is commercialized. Like Fig. 15, since this bone conduction speaker is attached around the ears, there is no hindrance at all to hear other sounds because the headset does not cover the ears, and it is never unnatural for hearing even when wearing it for a long time, and it is possible to recognize alarm signals to alert an approach of motor-car in any noisy environment.

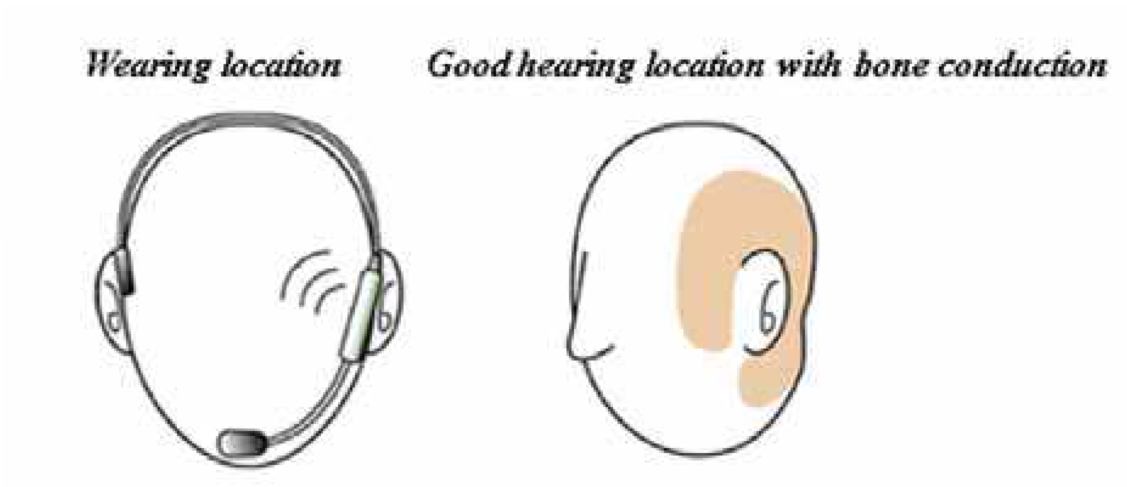


Fig. 15. Wearing location of the bone conduction safety helmet

Since this bone conduction can have the function of speaker only if it is attached around the ears, there is no hindrance at all to hear other sounds even when the headset does not cover

the ears. In addition, it is never unnatural for hearing even when wearing it for a long time, and it shows a big advantage that it is possible to recognize alarm sounds to alert an approach of motor-car in any noisy environment.
Therefore, we implemented a bone conduction safety helmet which connects the receiver with bone conduction speaker by using an existing general safety helmet. As explained previously, the function and operation mechanism of safety equipment is identical to that for safety equipment using the wireless proposed in the previous section, and it has the only difference that its method of expressing information on the approach of motor-car is the safety helmet using a bone conduction speaker. The prototype of manufactured safety helmet is divided into the equipment for vehicle and for worker which is identical to the safety equipment proposed in the previous section, and the speaker using a bone conduction vibrator is identical to Fig. 16. Since this bone conduction speaker was attached to the chinning string of safety helmet after being fastened and receives alarm sounds through bone conduction speaker, the worker can recognize hazardous factors immediately and evacuate because he/she can hear the ambient sounds and signal sounds transmitted from the motor-car at the same time since the ears of worker were not covered. All of the workers wearing safety helmets with manufactured bone conduction method and vehicles will communicate on a real-time basis, and the worker can check and grasp alarm sounds immediately through bone conduction and operation of LED if there is any motor-car or person existed when a motor-car approaches within the fixed distance.

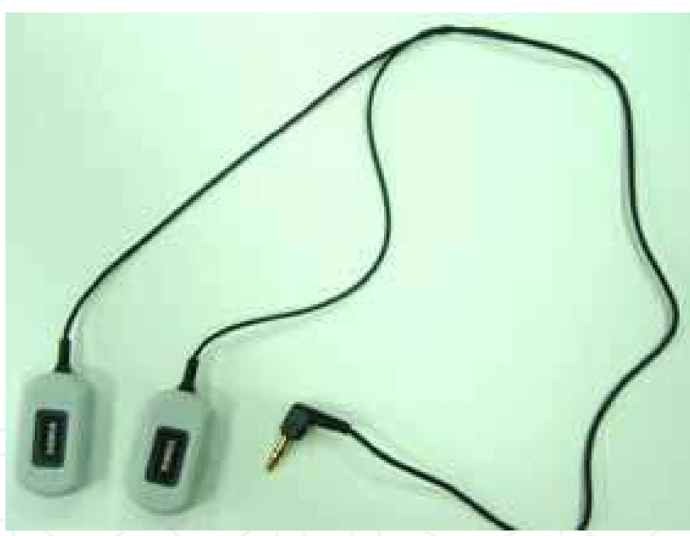


Fig. 16. Developed bone conduction vibrator speaker

The equipment for vehicle sends signals continuously while tracking the location of worker, and the receiver attached at the safety helmet of worker senses them and outputs alarm sounds and alarm signals in LED to the equipment for motor-car simultaneously. Bone conduction receiver attached at the safety helmet receives wireless signals transmitted from the vehicle as a top priority and can recognize that the motor-car is coming by using three stages of wireless signals through bone conduction speaker at the safety helmet of worker while working. Band of wireless signal for developed prototype of the safety helmet with bone conduction speaker is 448.75 Mhz, and used 5mW of output. Figure 17 is picture showing the result of final prototype of the proposed safety equipment which was manufactured in the form of safety helmet using the bone conduction speaker.

Fig. 17. Result of the prototype safety helmet for railways with bone conduction method

5. Conclusion

Since casualties of railway transportation occupy most of the recent railway accidents, it is steadily required to prepare the measure to prevent them. This paper described contents such as the applicability through design, manufacturing and field test of safety equipment developed as a measure to prevent casualties of maintenance worker working at the trackside of railway who corresponds to the employee as the target person of casualties, and the validation on utilization through its implementation in another form called as the safety helmet, etc. The safety equipment being proposed transmits alarm signals bidirectionally to the on-board and worker, and is consisted of the on-board safety equipment to be installed at the driver's cab of motor-car and the safety equipment for worker to be carried by the worker. Each safety equipment outputs information on entering motor-car in the front or information on worker in the form of various alarm signals, and can prevent and reduce casualties of railway transportation by enabling careful driving and evacuation to the safe area.

And, we performed field tests in the tunnel for metropolitan rapid transit which is the actual operation section to prove the effectiveness of developed safety equipment, and as a result of the test, the applicability was validated since requirements as the safety equipment to reduce casualties of worker were satisfied sufficiently. In addition, the possibility of utilizing this technology for safety equipment in various forms was verified by showing the prototype manufactured in the form of safety helmet using the bone conduction speaker by utilizing technologies for safety equipment being proposed. It is expected that the safety equipment having its superior performance and high possibility of utilization like this to prevent casualties of maintenance worker working at the trackside of railway will contribute much to the prevention and reduction of casualties in railway transportation in the future.

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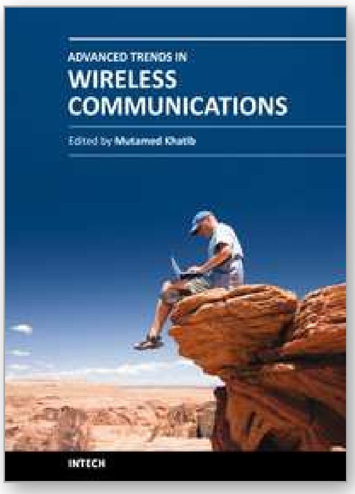

Advanced Trends in Wireless Communications

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Physical limitations on wireless communication channels impose huge challenges to reliable communication. Bandwidth limitations, propagation loss, noise and interference make the wireless channel a narrow pipe that does not readily accommodate rapid flow of data. Thus, researches aim to design systems that are suitable to operate in such channels, in order to have high performance quality of service. Also, the mobility of the communication systems requires further investigations to reduce the complexity and the power consumption of the receiver. This book aims to provide highlights of the current research in the field of wireless communications. The subjects discussed are very valuable to communication researchers rather than researchers in the wireless related areas. The book chapters cover a wide range of wireless communication topics.

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