Promoting the Digitization of Japanese Fire Prevention/Emergency Wireless Communications Systems

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Abstract

Japanese fire prevention/emergency wireless communications systems, presently run through analog wireless communications, are being upgraded to digital wireless communications. The digitization of these systems makes it possible to expand the area of communication between mobile stations thanks to base station loopback communications, but on the other hand, this expansion of the communication area leads to new operational issues, such as radio wave interference and frequency changes. This paper introduces the efforts made by NEC to solve these issues while making full use of the advantages of digitization.

Keywords

software-defined radio, dual radio, different-channel grouping, non-permanent transmission system, radio wave interference, auto channel-switching of mobile stations, fire prevention, emergency digital wireless communications, SCPC

1. Introduction

Japanese fire prevention organizations are typically organized by municipality. In the case of small municipalities, sometimes more than one of them forms a broad-area or association-type organization equivalent to a single municipal fire prevention organization. Their operations are centered around the firefighting/life-saving activities that begin with the reception of 119-dialed emergency reports. Between emergencies, they also develop preventive campaigns, such as surveys and guidance for optimal installation, maintenance and management of fire prevention facilities whenever a location that gathers a large number of people or a building handling hazardous materials is built, extended or reconstructed.

To streamline these firefighting/life-saving activities, municipal fire prevention organizations began about four decades ago to construct fire prevention/emergency wireless communications systems. Meanwhile, the Protection of Personal Information Act has been enforced since 2003, making it necessary to keep personal information secret even in firefighting/life-saving activities.

Based on the above background, the Japanese government decided that the fire prevention/emergency wireless communications systems of municipal fire prevention organizations should be moved from analog transmission on the 150 MHz band to digital transmission on the 260 MHz band, with the aim of promoting effective use of frequency resources, protection of privacy and active use of data communications. In FY2010, the Japanese Ministry of Internal Affairs and Communications decided to conduct demonstration experiments as a trigger for this switch. Fire prevention organizations all over Japan are now requested to digitize their analog wireless communications systems by May, 2016.

At NEC, we are developing systems to cope with a wide range of digital wireless communications to meet the digitization needs of Japanese fire prevention/emergency wireless communications systems.

2. Features of the Digitization of Fire Prevention/Emergency Wireless Communications Systems

The new fire prevention/emergency digital wireless communications systems adopt the SCPC (single channel per carrier) method as their communication method and use an audio codec exclusive to fire prevention systems for improved confidentiality.

While in traditional analog wireless communications fre-

quencies were allocated in simplex for fire engines and in duplex for ambulances, in digital wireless communications frequencies are allocated without distinction between fire engines and ambulances but so that the base station transmission waves and mobile station transmission waves form pairs. This has improved the smoothness of mobile station communications between fire engines and ambulances.

The mechanism of the system has also been changed from the method that emphasizes direct communications between units at disaster sites to the one that emphasizes base station loopback communications.

When observing the features of the digitization of a wireless communications system from the viewpoint of operations not technology, it will result in the following improvements:

- Improvement of confidentiality thanks to the use of a fire prevention-exclusive codec
- Expansion of the area of communication between mobile stations thanks to base station loopback communications (**Fig. 1**)
- Facilitation of ID-based system linkage thanks to digital wireless station ID management

On the other hand, the expansion of the communication area results in an increase in wireless traffic and the superimposition of the same frequencies, which then leads to new issues such as radio wave interference and blind zone generation.

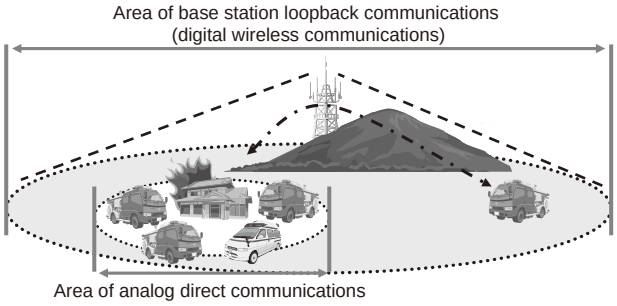


Fig. 1 Comparison of communication area between analog wireless and digital wireless communications.

3. Features of the Wireless Communications of Fire Prevention Organizations

As seen in **Fig. 2**, fire prevention organizations use wireless communications for a "simultaneous disaster notice" that announces the occurrence of a disaster and orders a rush to the site, "disaster site communications" for sharing information at the disaster site, "select calls" for highly confidential communication of the situation of emergency transported persons from the ambulance to the command center or hospital and "daily liaisons" such as communications related to preventive inspection operations.

When a disaster occurs, a simultaneous disaster notice ("call-out") is issued to transmit the details of the disaster and the units (vehicles) to be put in action so that all of the units in the jurisdiction can send the required units to the disaster site. This is one of the characteristic uses of wireless communications by fire prevention organizations. To transmit the notice to all of the units in the jurisdiction without exception, the command center should also send the same information through wireless com-

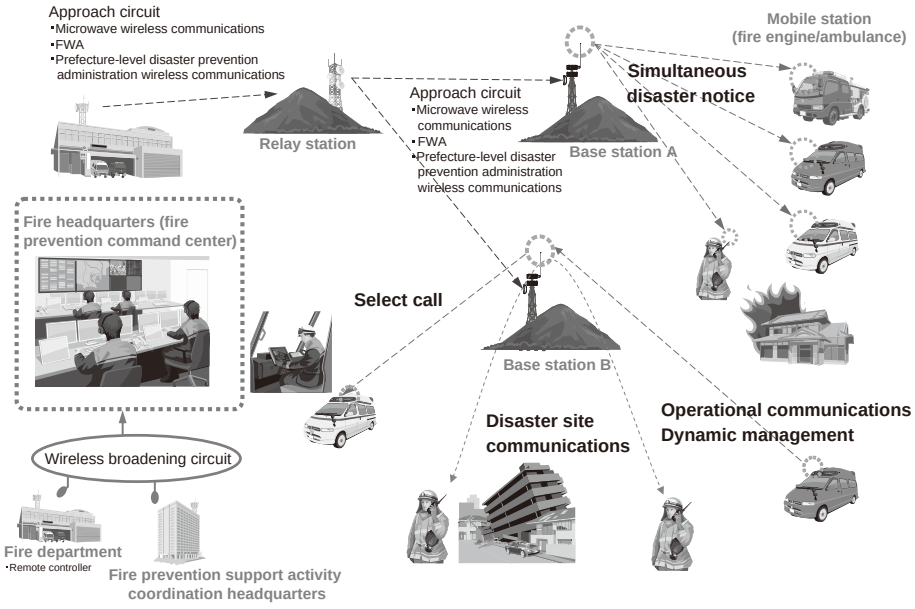


Fig. 2 Wireless communications in a fire prevention organization.

munications to the vehicles working outside the fire department.

This notification of all of the vehicles working outside the department is possible by transmitting the information on all available frequencies using all of the base station wireless equipment in the jurisdiction. However, if multiple base station wireless equipment are communicating using the same frequency, the radio waves will interfere with each other in the areas where they are superimposed and the message might become hard to decipher (**Fig. 3**). There is an alternative method in which the simultaneous notice is transmitted using a different frequency for each base station to avoid radio wave interference. Nevertheless, if different frequencies are used, it is impossible to establish communications between mobile stations using different frequencies, which hinders the sharing of information between units (**Fig. 4**).

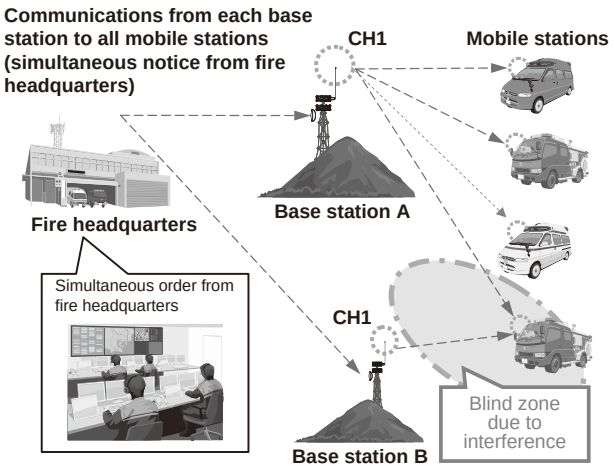


Fig. 3 Radio interference caused by simultaneous notice.

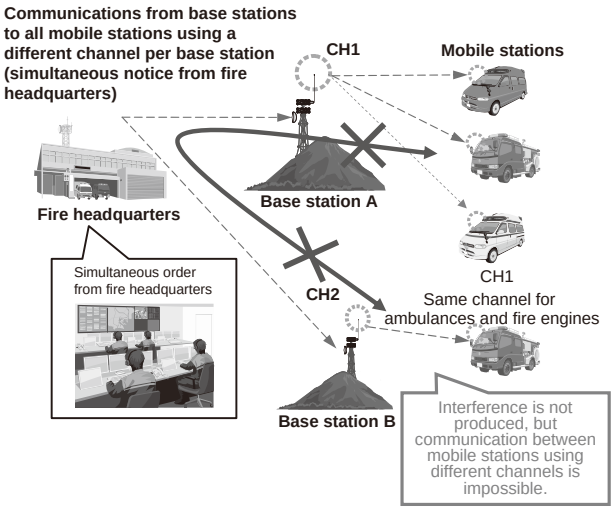


Fig. 4 Channel switching per base station.

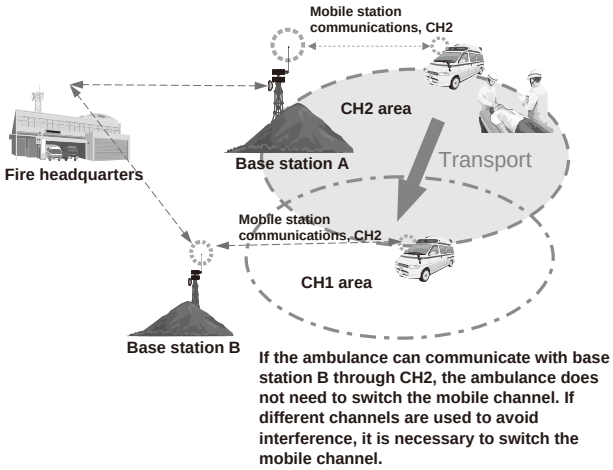


Fig. 5 Channel switching per area.

Furthermore, ambulances run outside the areas assigned to them in order to transport injured and sick people to hospitals. If the wireless communications frequency is changed for each relay station in order to address the issue of radio interference mentioned above, each ambulance during transport would be required to change its mobile channel whenever it enters a different wireless communications area (**Fig. 5**).

Since ambulances must transport seriously injured people with a small crew, it is a significant burden to have to switch the mobile frequency for each wireless communications area.

4. Considerations in the Digitization of Fire Prevention/ Emergency Wireless Communications Systems

The wireless communications of fire prevention organizations need to take the following two points into consideration:

- Countermeasures against the radio wave interference accompanying simultaneous disaster notices
- Matching with base station frequencies when the mobile station of an ambulance moves between areas covered by different wireless base stations

If a different transmission frequency is allocated to each base station to avoid the radio interference accompanying simultaneous notices, the frequency to be used in each base station communications area is specified and the mobile station needs to switch its frequency as it enters each area. On the other hand, if the same frequency is allocated to all base stations to avoid the inconvenience of frequency-switching by mobile stations, radio wave interference may occur when a simultaneous notice is issued.

To digitize a fire prevention/emergency wireless communications system, it is necessary to solve these conflicting requirements.

4.1 Automation of Mobile Station Frequency Switching

The issue of frequency switching by mobile stations can be solved by introducing the permanent transmission system already in use by cellular phones, in which base stations transmit radio waves continuously and each mobile station selects the optimum base station and frequency according to its radio wave receiving conditions. However, since the permanent transmission system involves outputting radio waves continuously, it often encounters difficulties in obtaining permission due to concerns about radio interference in other municipalities using the same radio frequencies.

We therefore decided to use the vehicle operation terminal equipment that is already installed in fire engines and ambulances to track the location of each vehicle and transmit it to the command center. We developed and provided a non-permanent transmission system in which the vehicle operation terminal equipment automatically selects the frequency to be used according to the position information of the vehicle, switches the frequency of the mobile station and notifies the base station transmitting and receiving radio waves in the current area of the new frequency. This system allows each mobile station to automatically select the optimum base station and frequency in each communication area.

4.2 Establishment of Mobile Station Communications Using Different Frequencies

With a system designed to avoid the radio interference accompanying simultaneous notices, there is the issue of the impossibility of information sharing between units because communications cannot be established between mobile stations using different frequencies.

A possible solution for this issue is to provide a function by which central equipment groups the content of communications over different frequencies, like those carried on a single frequency (different-channel grouping).

This function makes it possible to secure communications between mobile stations using different frequencies while avoiding the issue of the radio interference accompanying simultaneous notices. Then, it achieves to share information among the units at the disaster site as well as among units standing by at headquarters or at dispatched locations to prepare for expansion of the scale of the disaster (**Fig. 6**).

Recently, various factors, such as improvements in the effectiveness of preventive inspection operations for giving fire-prevention guidance to building managers and advancements in the fireproofing of buildings, have considerably decreased the opportunities for fire crews to be engaged in actual firefighting activities. This is also regarded as one of the issues facing fire prevention organizations.

Although experience can be simulated realistically through

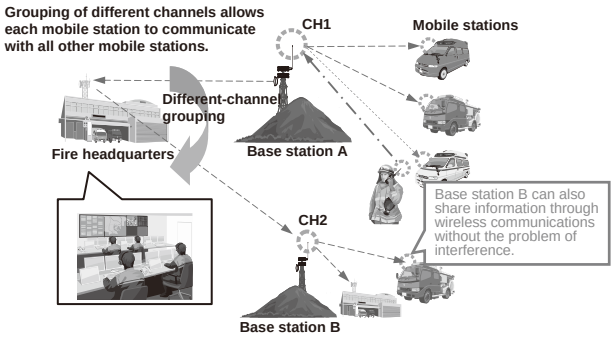


Fig. 6 Outline of different-channel grouping.

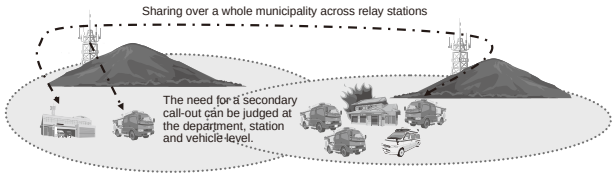


Fig. 7 Sharing of disaster conditions through different-channel grouping.

fire simulators and various training facilities, fire headquarters are still looking for mechanisms to share real disaster site conditions among all crews, with the aim of maintaining and improving their skills in spite of the reduction of actual experience. By establishing the mechanism of communications between mobile stations using different frequencies (different-channel grouping) as described above, we have made it possible to share disaster site conditions throughout the entire fire headquarters, including subordinate departments and stations, from the simultaneous disaster notice to the arrival of all units on-site (**Fig. 7**).

5. Further Potential for Fire Prevention/ Emergency Wireless Communications Systems

The digitization of the fire prevention/emergency wireless communications system not only improves the confidentiality of communications and expands the area of communications between mobile stations, but also enables various system linkages based on wireless device ID. **Fig. 8** shows a system that automatically displays the case with which each ambulance is occupied based on the wireless communications received from it. This is made possible because, when the fire prevention command center responds to a wireless communication from an ambulance, the calling mobile station can be identified by its wireless device ID.

The wireless device ID also makes it possible to record wireless communications from vehicles dispatched for actions or sent to other fire departments. Then, it displays the record of

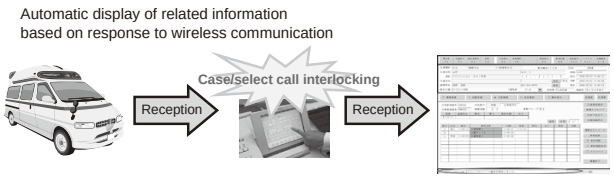


Fig. 8 Case/select call interlocking based on wireless device ID.

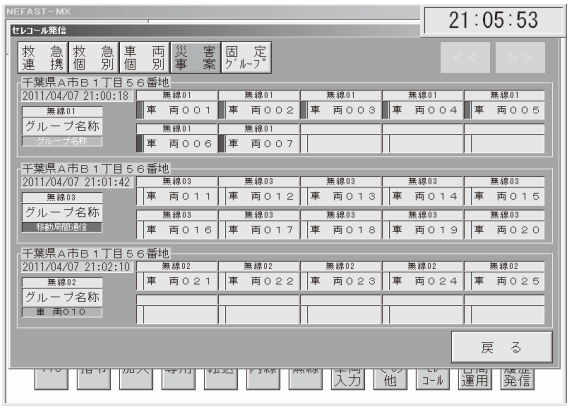


Fig. 9 Case-specific simultaneous wireless communications control display.

Fig. 10 Wireless call registry control display.

call registry on the screen similar to the one of mobile phone, so that the vehicle can be called back with a single-tap operation.

It is also possible to group the vehicles involved in the same disaster case and send them wireless simultaneous notices (**Fig. 9**). With these wireless simultaneous notices, it is possible to group wireless communications even when the mobile stations are using different frequencies. The call register can also facilitate communications with vehicles that are not occupied with a disaster case, such as vehicles dispatched for flood prevention and other operations (**Fig. 10**).

To deal with the diversification and expanding scale of disasters, the aging population combined with the declining birth rate and the increase in emergency cases accompanying the trend of nuclear families and to the promote smooth digitization of fire prevention/emergency wireless communications systems, the Japanese government is enhancing firefighting capabilities at the same time as broadening coverage and promoting fire prevention collaboration with the aim of the efficient utilization of facilities.

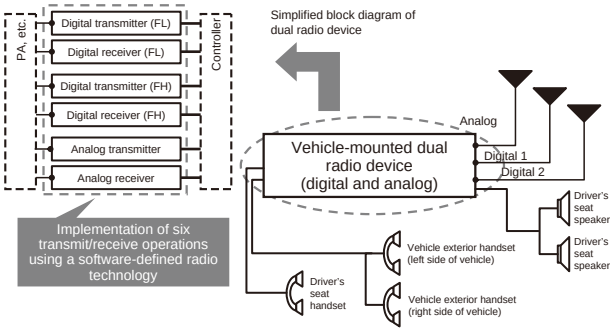
In a small-scale fire prevention organization, the number of wireless relay stations and frequencies managed by a command center is one or two and the number of vehicles is about ten. When several small organizations are grouped to cover a broader area or their collaborations are enhanced, the number of managed wireless relay stations and frequencies increases to between ten and twenty and the number of vehicles to several dozens. These increases make the selection and control of wireless communications and vehicles more difficult jobs, making it necessary to add new staff for these operations.

The functions described above, such as case/select call interlocking, case-specific simultaneous wireless communications and call registry display, are expected to facilitate the selection of wireless communications and vehicles even when they increase as a result of broadening fire prevention coverage and collaboration between organizations and to enable command operations with smaller crews.

6. Software-defined Radio Communications Technology

Finally, we will introduce the software-defined radio communications technology we adopted for the digitization of fire prevention/emergency wireless communications systems. This technology implements in software the radio communications (modulation, audio encoding/decoding, transmission method, etc.) that have previously been implemented in hardware. It installs multiple pieces of software on a single piece of hardware so that users can select the software required for their operations and modify radio communications properties easily as required (**Fig. 11**).

Japanese fire headquarters have been requested to digitize their fire prevention/emergency wireless communications systems over a long period from 2010 to May 2016. During this period, consequently, fire headquarters with digitized communications and those with non-digitized communications coexist in Japan. This means that, if a large-scale disaster occurs necessitating mutual aid between headquarters, communications between fire headquarters using digital and those using non-digital communications will be impossible. NEC's software-defined radio communication technology can be the solution for this issue because it can implement both analog and digital wireless communications with a single piece of wireless device.



1. Digital/analog switching on single wireless device
2. Built-in handset select switch
3. Built-in audio output mixer

Fig. 11 Outline of a wireless communications system using a software-defined radio technology.

7. Conclusion

In this paper, we explained the digitization of fire prevention/emergency wireless communications systems, identified the accompanying issues and introduced our efforts to solve them. We are determined to make full use of our software-defined radio technology in promoting the digitization of fire prevention/emergency wireless communications, solving the accompanying issues and presenting new possibilities for fire prevention organizations.

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