Development of alarm network using Earthquake Early Warnig

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ABSTRACT :

In Mikawa area, the central area of Japan, many automobile plants and machine factories are locating there, unfortunately it is also one of the most risky regions for large earthquakes in Japan. The Disaster Prevention Research Center（DPREC）, Aichi Institute of Technology(AIT), Japan, has organized a consortium which composed of enterprises in this area in order to mitigate seismic disaster. One of main research topics of DPREC is to re-distributing the Earthquake Early Warning (EEW) system, which is developed by Japan Meteorological Agency. The system is used for seismic disaster reduction because it can provide prior information such as, workers-evacuation and stopping line-system and so forth before the generation of strong earthquake shaking. Another one is to estimates seismic intensity and send them to plants, factories and offices in Mikawa area through internet system before S-wave arriving. The DPREC also has installed a seismometer network in the area aiming at getting observed seismic intensity and compare it with estimated one.Besides, the PC monitor installed at a central office can display information, such as epicenter, magnitude, seismic intensity and arriving time which is estimated by EEW. It also can animate P and S-wave propagating front and display it. The DPREC get observed seismic intensities from observing sites through the web system and send back the map of seismic intensities to monitor at other sites at once. The re-distribute EEW system developed by DPREC, now, has been installed at about fifty factories and works for seismic disaster prevention successfully.

KEYWORDS: Earthquake Early Warning, alarm network, Emergency information

1. Introduction

Mikawa area, in central Japan, is one of the most risky areas for large earthquakes in Japan. On the other hand, many automobile plants and machine factories including Toyota motor company are located, so that this area is one of the most industry-accumulated areas in Japan. To prevent this area for earthquake disaster is very important and emergent problem.

Disaster Prevention Research Center（DPREC）, Aichi Institute of Technology, Japan, has organized the Consortium with enterprises in Mikawa area. Main research of DPREC is to re-distribute the Earthquake Early Warning (EEW) developed by Japan Meteorological Agency. DPREC estimates seismic intensities and arriving time (or postponement time) by using EEW information and sends them to EEW terminals installed at plants, factories and offices in Mikawa area by using internet system several and dozens seconds before arriving strong motions. The system is useful for earthquake disaster reduction by performing workers-evacuation and stopping machines and line-system before arriving strong shaking.

However, accuracy of estimated intensity and arriving time are not so high because EEW information (estimated origin time, hypocenter, magnitude) and other empirical equations for calculation have errors. For example, an amplification factor of soil is estimated from geological and topographical data of a target site, therefore includes also errors. So that accuracy of estimated seismic intensity must be checked for practical use. A seismometer network has been installed at each site for observing seismic intensities and comparing with estimated seismic intensities by EEW.

DPREC developed the EEW terminal system which can receive EEW and estimate seismic intensity and arriving time at a factory or an office of a company. Animated P and S-wave propagating fronts from epicenter toward a target site is displayed on a monitor. Estimated seismic intensity and margin time before arriving strong motions are also displayed on the monitor. Seismic intensities observed by seismometers at sites are took

back to the server at DPREC on time by internet system and send back the distribution map of seismic intensities which can be displayed on a monitor at companies.

The system developed by DPREC has already started to distribute EEW at about fifty factories and offices in Mikawa area for practical uses, such as worker's evacuation, control of facilities, stopping lines, etc.

2. Earthquake Early Warning (EEW) System

2.1 EEW Information System

Japan Meteorological Agency（JMA）has started to serve EEW which includes an origin time, a hypocenter and a magnitude estimated by using P-wave information observed at nationwide seismometer network installed by JMA and National Research Institute for Earth science and Disaster Prevention. JMA informs EEW to users including second supplier within five seconds(average) after detecting P-waves. Disaster Prevention Research Center (DPREC), Aichi Institute of Technology, Japan, receives EEW and informs offices and factories in Mikawa Area, Japan, of EEW from several and dozens of seconds before arriving strong motions. Fig.1 shows the conception diagram of EEW system.

Fig.2 shows the distribution system. JMA informs EEW to the Japan Meteorological Business Support Center (JMBSC) by dedicated lines. DPREC receives EEW from JMBSC by IP/VPN and distributes it EEW to about fifty sites (offices and fabrics) by internet dedicated lines (ADSL, ISDN or optical fiber line) within one second.

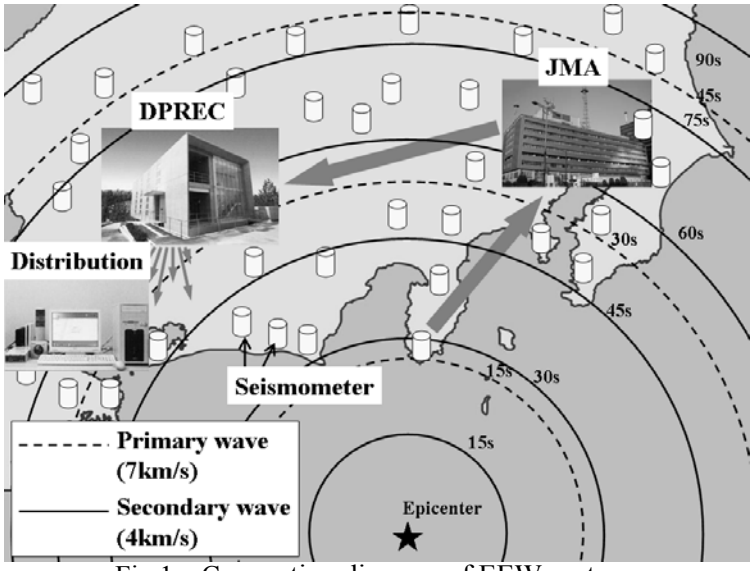

Fig.1 Conception diagram of EEW system.

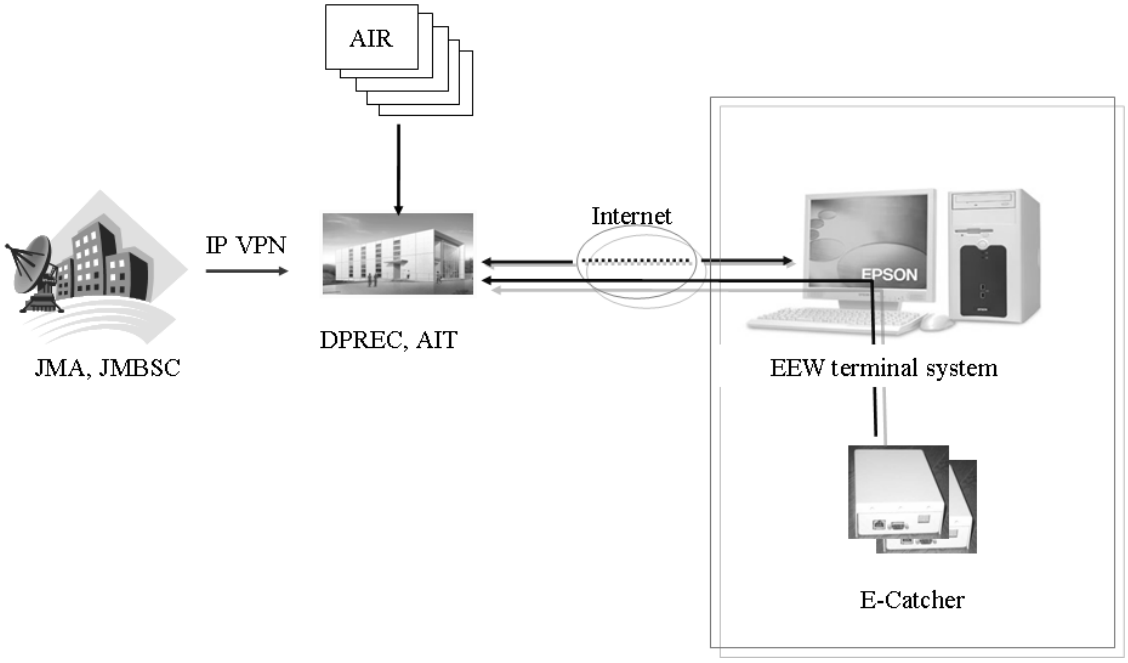

Fig.2 Earthquake Early Warning (EEW) distribution system.

2.2 Estimation of seismic intensity and arriving time

EEW includes the information on an origin time, a hypocenter and a magnitude of an earthquake. Seismic intensity at a target site is estimated by the following procedure.

(1) Mj (Japan Meteorological Scale magnitude) is transformed to Mw (moment magnitude)
Mw=Mj-0.171 (Utsu:1982) (1)

(2) Peak ground velocity PGV600 on firm basement with Vs 600m/s is calculated by using the empirical attenuation formula as follows(Shi and Midorikawa:1999)
logPGV600=0.58Mw+0.0038D-1.29-log(x+0.0028×10**(0.50Mw))-0.002x (2)
Here, D is depth and x is hypocentral distance

(3) Average shear wave velocity AVS of subsoil down to 30m in depth is calculated by the following equation (Matsuoka and Midorikawa:1994).
logAVS=a+blogH+clogD (3)
Here, H is ground level and D is distance from a large river. Coefficients a, b, c are determined by geological and topographical conditions of soil at the site.

(4) Amplification factor ARV from firm basement to ground surface is calculated by
logARV=1.83-0.66logAVS (4)

(5) Peak ground velocity on surface is calculated by (5)
PGV=PGV600×ARV (5)

(6) In the last seismic intensity (Japanese scale) is estimated by (6) (Midorikawa et.al:1999)
I=2.68＋1.72logPGV (6)

Arrival time is (Postponement time) is calculated from a hypocentral distance and seismic velocity structure of underground.

3. Distribution System of EEW

3.1 Network System

Fig.3 shows a network system in Mikawa Area installed by DPREC. Triangular symbols show the sites (factories) at where the terminal system composed of EEW receiving PC and E-catcher type seismometers are installed. Open circles and squares show the places where ETNA type seismometers and AIR type seismometers are installed respectively.

E-catcher type seismometer has real time communication function which can send observed seismic intensity in Japanese scale Ij, maximum acceleration αmax and spectral intensity SI to the main server installed at the DPREC office via PC terminal system by through internet. ETNA type seismometer does not have real time communication function, however can obtain high quality data with high sensitive sensors. The data are sent by PHS lately. AIR type seismometer has high sensitive sensor and send high quality on-line data to the DIPREC server.

EEW terminals and three types of seismometers are installed every 20km in Mikawa Area, and connected mutually through the server in DPREC via internet. By using this network system (Ai-system), EEW and observed seismic intensities are distributed to users who can confirm arriving seismic motions on the monitor in the terminal system at their office and fabrics on-time.

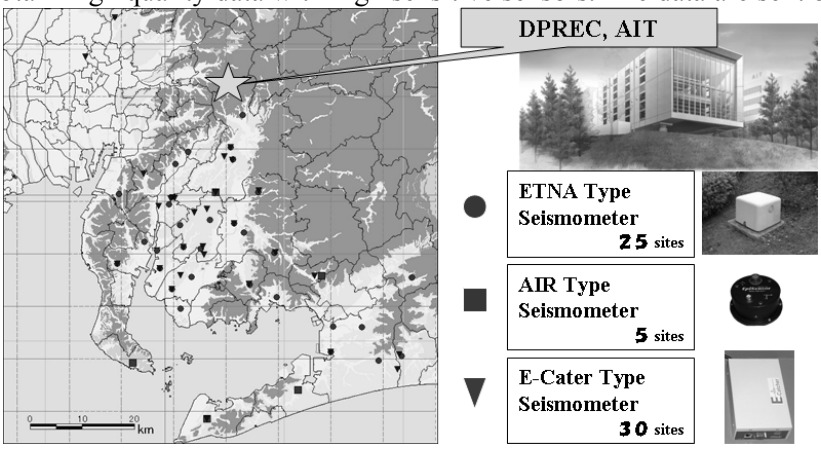

Fig.3 Network system in Mikawa Area installed by DPREC.

3.2 Terminal system

As shown in Photo 1, a terminal system is consist of a router, a main body of PC, a monitor, an alarm device, a

contact box for controlling machines and facilities, digital cameras, a pair of E-catcher seismometers and a no blackout device by basic constitution.

Fig. 4 shows the monitor screen which can display the information as follows.

(1) An epicenter and dynamic state of propagating P-wave (yellow) and S-wave (red) front from an epicenter to predicting site (upper central). Estimated seismic intensity and a margin time before arriving strong motions at a factory (upper left).

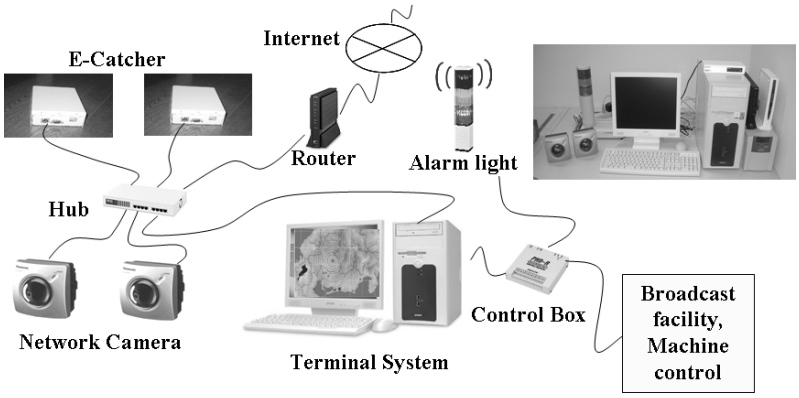

Photo 1 Terminal system installed at sites.

(2) On-time data of acceleration and seismic intensity observing by AIR type seismometers installed at five sites (central left).

(3)~(5) Time histories of seismic intensity, acceleration and SI value at the site predicted where E-catcher seismometers are installed. Two lines show values observed by two seismometers at different positions (bottom left).

(6) Outside state monitoring by cameras (bottom right).

(7) Seismic intensity distribution observed by E-catchers at other companies marked by circles. Color shows maximum intensity observed by that time at that site. Changes and increasing of seismic intensities are displayed at other companies. Propagation of strong motions in this area can be also understood (upper right).

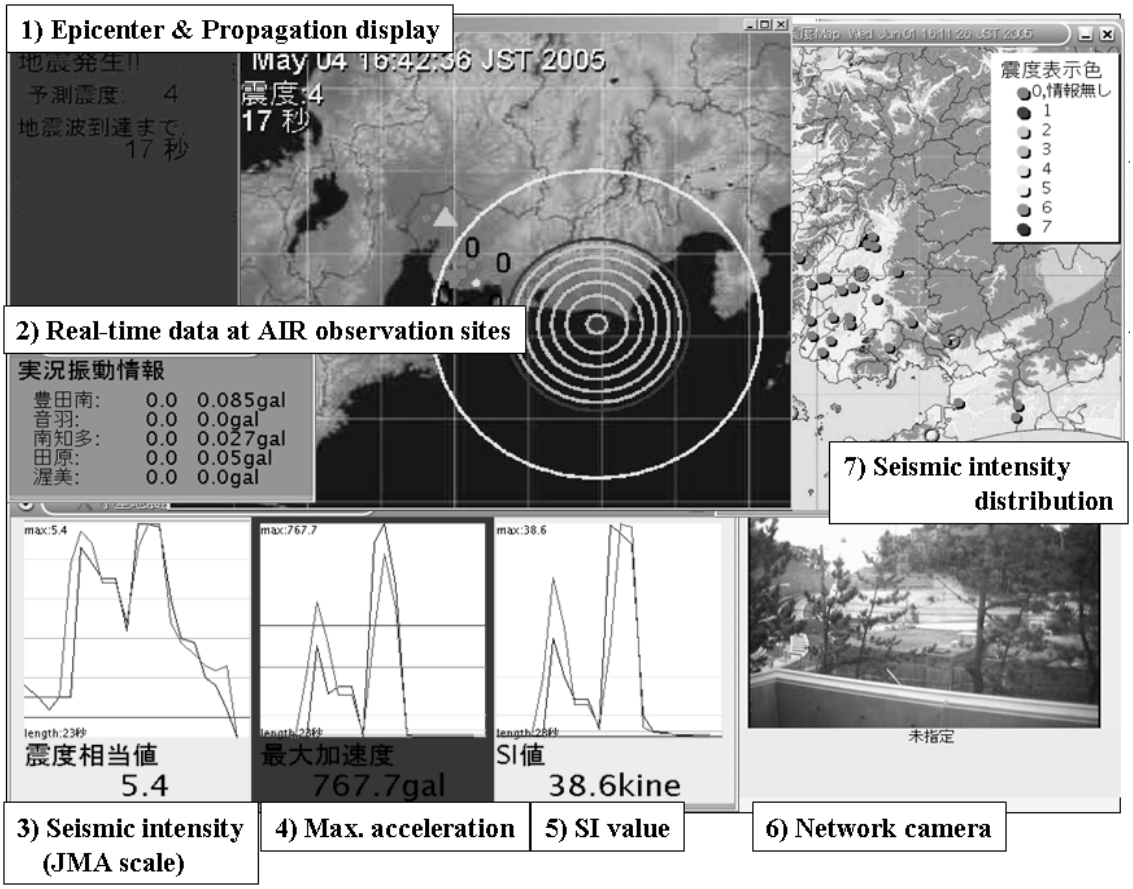

Fig.4 The monitor screen which can display the information.

4. Practical use of EEW system

4.1 Companies and organizations distributed

DPREC distributes EEW information to thirty companies which are mainly manufacturing industries (automobile, machinery, chemical materials, etc) including big companies employed a member of several thousand employees and small ones. University, school and medical facilities are also included. Some companies have several offices, factories and plants at other locations far from head office. So DPREC distributes EEW to about fifty places in total.

Fig.5 shows a new system developed recently for the users who are attending to introduce EEW system in his other factories. A host server installed in the main office receives EEW from the DPREC server and redistributes EEW to terminals in other factories via internet or LAN.

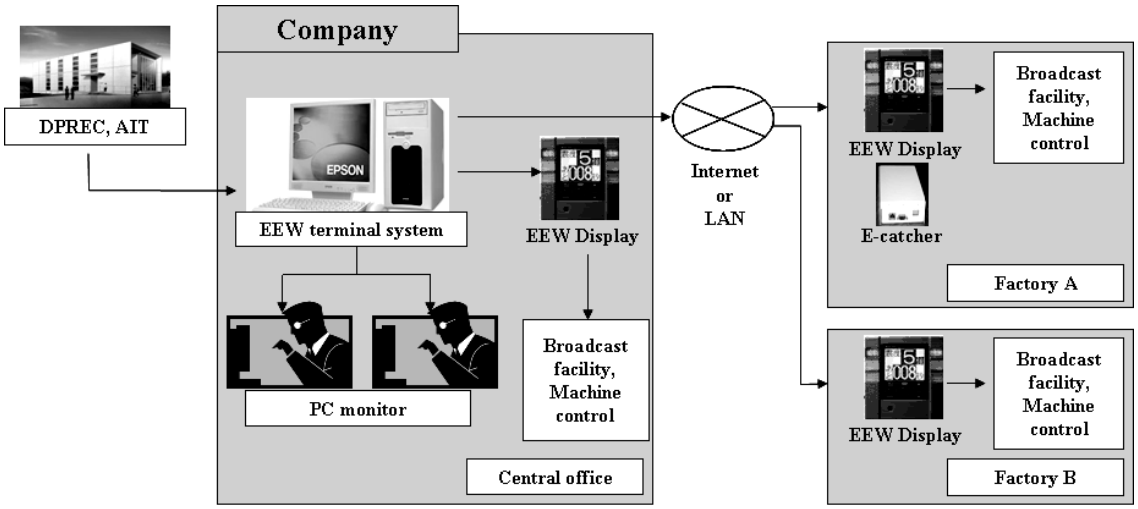

Fig.5 New system developed recently for the users who hopes to introduce EEW system in his other factories.

4.2 Examples of practical use

In Japan, EEW is used in many cases, for examples: factories, train, school, elevator control, construction site, etc. In the group of DPREC main purpose of using EEW is for evacuation of employees in factories with alarm buzzer and sound broadcast by emergency broadcast facilities triggered automatically by EEW. Aichi Institute of Technology starts this system for evacuation outside from lecture rooms and laboratories with alarm buzzer and sound broadcast. All students and professors are required to act evacuation as soon as possible, maybe within several seconds from EEW alarm.

Photo 2 shows an example of shutdown system by a valve attached to a tank of toxic materials. In semiconductor factories, EEW also is used for stopping facilities which supply dangerous liquid and materials. In some offices, use of EEW is planning to stop elevators at nearest floor and open its door before arriving strong motions.

Photo 2 Example of shutdown system by a valve attached to a tank of toxic materials.

5. Summary

Disaster Prevention Research Center (DPREC), Aichi Institute of Technology, Japan, developed the re-distributing system of Earthquake Early Warning (EEW) distributed by Japan Meteorological Agency and has started to inform about thirty companies in Mikawa Area, central Japan, of estimated seismic intensity at the company site via internet several or dozens seconds before arriving strong motions. The companies are making use of that system for employees-evacuation, controlling facilities, stopping machines, etc. The system developed in this study should be very useful for earthquake reduction not only at companies but also at other organizations such as schools, hospitals, social institutions, etc.

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References

1)Matsuoka Masashi and S., Midorikawa: The Digital National Land Information and Seismic Microzonation, 22th symposium on ground motion, 23-34, 1994

2)Utsu Tokuzi: Relationships between earthquake magnitude scales, Bull. Earthq. Res. Inst., vol.57,465-497,1982

3)Si Hongjun and S., Midorikawa: New attenuation relationships for peak ground acceleration and velocity considering effects of fault type and site condition, J. Struc. Constr. Eng., AIJ, No.523, pp.63-70, Sept., 1999

4)Midorikawa Sabroh, K. Fuzimoto and I., Muramatsu: Relationship among measured seismic intensity, JMA seismic intensity and strong motion index, Journal of Institute of Social Safety Science1999