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DEVELOPMENT OF METHODOLOGY FOR EVALUATING GROUND MOTION PARAMETERS AND INFORMATION SYSTEM UNDER SEISMIC EMERGENCY

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SUMMARY

The R&D program which is concerned with the real-time earthquake information system has been conducted at Japan Atomic Energy Research Institute since 1996 within the framework of “Frontier Research Programs on Earthquake” promoted by Science and Technology Agency of Japanese Government.

In this program are being developed the estimation methodologies on hypocenter, fault parameters and earthquake motion, which is applicable to the real-time information system and the damage evaluation in the urban area concerned. In order to examine the estimation methodologies and the concept of information system, the seismic emergency information system, which estimates and transmits the earthquake information, is also being developed as an examination system.

In order to examine the evaluation methodologies and performance of the system, the region around Tokai Research Establishment of JAERI was selected and the soil database was prepared. Besides, the distribution of earthquake motion under scenario earthquakes in this region were estimated using the evaluation methodologies developed in the program. This paper describes the basic concept of the system and the current status of the program

INTRODUCTION

By the Hyogo-ken Nanbu earthquake (January 17, 1995), the serious damages in structures and lifelines around Kobe were caused and more than 6000 people were killed as the result. Due to the confusion and luck of reliable information, there was a delay in taking the appropriate initial management against disaster mitigation. Through the experience of this earthquake, the importance of initial management under the seismic emergency has been emphasized. Thus, one of the most urgent issues in seismic disaster mitigation has been to establish an information system applicable to prompt decision making including the estimation of the detailed earthquake motion before the real damages is informed.

From the above background, a R&D program which is concerned with the real-time earthquake information system has been conducted at JAERI(Japan Atomic Energy Research Institute) since 1996 within the framework of “Frontier Research Programs on Earthquake” promoted by Science and Technology Agency of Japanese Government [Ebisawa et.al., 1999a, 1999b]. This R&D has been carried out under the coordinated program between JAERI and NIED(Natianal Research Institute for Earth Science and Disaster Prevention).

The program involves the development of estimation methodologies of hypocenter, fault parameters and earthquake motion which are applicable to the real-time information system and the damage evaluation in the urban area concerned. In order to verify the estimation methodologies and the concept of information system, the

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seismic emergency information system, which transmits the earthquake information of hypocenter and earthquake motion to users , is also being developed as an examination system. In the development of this system, use of the existing seismic monitoring networks in real-time is considered.
Main features of the R&D and functions to be incorporated in this system are;

(1) Function to unify the different format in time history data from various existing seismic monitoring networks,
(2) Methodology to estimate the location of the hypocenter and magnitude within one minute, and the fault parameters such as seismic moment and corner frequency within three minutes,
(3) Methodology to estimate promptly the earthquake motion parameters such as maximum acceleration, seismic intensity, spectrum and time history considering the vibration amplification caused by soft deposit soils and topographic irregularities, and also by correcting promptly the distribution of earthquake motion obtained in advance by simulating the large earthquake,

In order to examine the estimation methodologies and performance of the system, the region around 30 km of Tokai Research Establishment of JAERI was selected as the test field. The soil database on shear wave velocity, relationship between equivalent shear modulus vs. shear strain, and damping ratio vs. shear strain every 500 m square mesh in the area around JAERI-Tokai site are being prepared.
Test network which consists of three seismometers with the k-net specification and others was prepared for the examination of the system. Besides, the distribution of earthquake motion under scenario earthquakes in this region were evaluated using the estimation methodologies developed in the program.
This paper describes the basic concept of the system and the current status of the program; development of estimation methodologies, the earthquake monitoring network in the region around the Tokai site of JAERI, soil database, and the results of ground motion distribution estimation under the scenario earthquakes.

BASIC CONCEPT OF THE SYSTEM

The seismic emergency information system is being developed based on the following concept .

Utilization of existing seismic monitoring networks in real-time

The system requires the time history data of the earthquake motions obtained from multiple existing seismometer monitoring networks in real-time. In order to confirm the feasibility of this idea, a technique, by which the time history data can be transmitted in real-time, will be examined to realize the required improvement to the seismometer used in a non-real-time seismic monitoring network

Capability responding to the diverse needs of users considering the relation between estimating time and accuracy of earthquake motion parameters

The requirements of earthquake information users with respect to the accuracy and estimating time of earthquake motion parameter are diverse in general. In order to respond to such various needs of multiple users, the system will be designed to provide for arbitrarily option of multiple methodologies considering the mutual relation between the estimating time and accuracy of earthquake motion parameters.

Improvement of estimation accuracy by preparing for related databases and preliminary evaluation

It is premised that required databases for estimating the earthquake motion parameters are prepared and qualified and preliminary evaluation to improve the accuracy can be utilized. The databases include the detailed soil data concerning nonlinear characteristic of the surface soil and topographic irregularity, and predicted distribution of the earthquake motion under scenario earthquake in the region concerned.

Consideration of user environment

In order to respond to the diverse needs of multiple user environments, the system will be designed considering the various user environments. Moreover, the liaison with the user system which involves an advanced geographic information system (GIS) will be investigated in order to attain the practical and effective use of earthquake motion parameters.

SYSTEM CONFIGURATION AND FUNCTIONS

The seismic emergency information system has been being developed based on the above mentioned concept. This system consists of six subsystems as shown in **Fig.1**. The outline of each subsystem is described below.

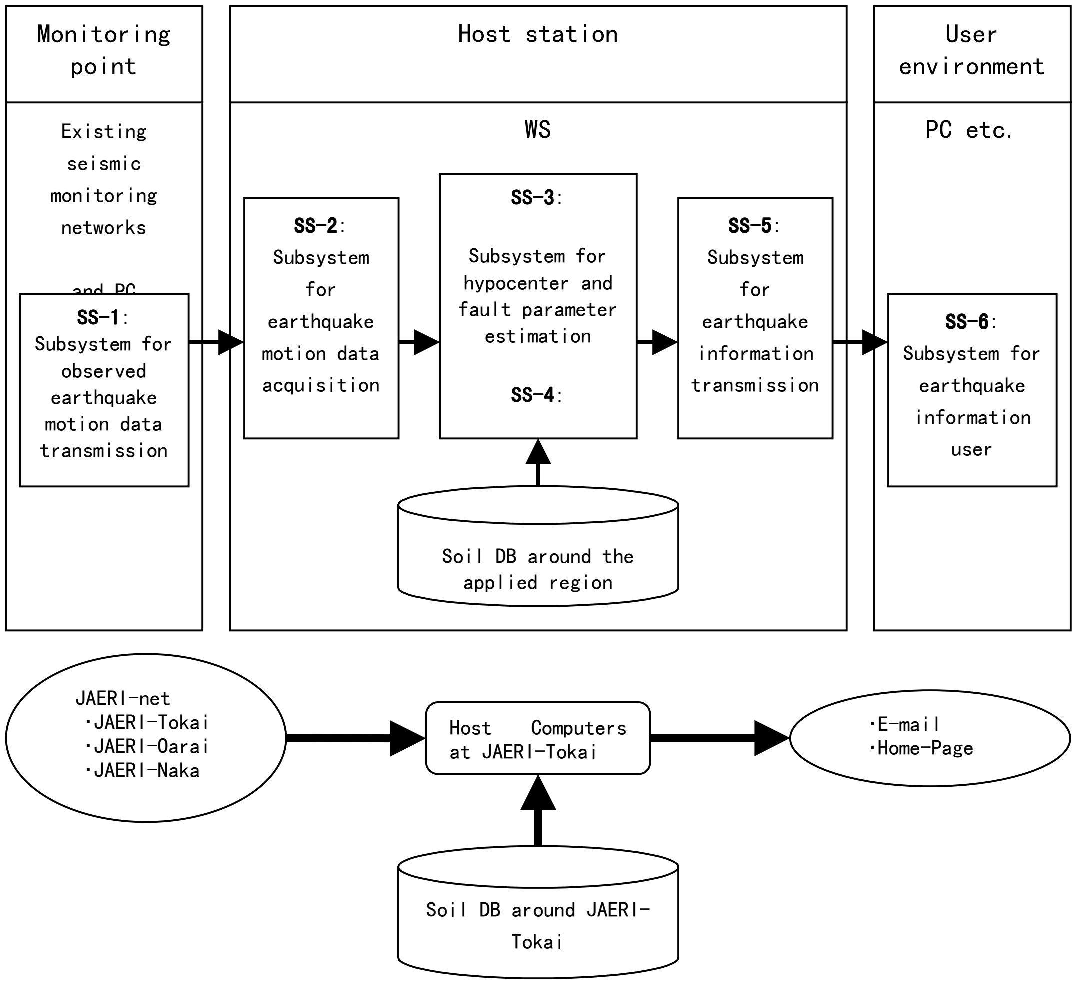

Fig.1 Configuration of the seismic emergency information system

Subsystem for observed earthquake motion data transmission(SS-1)

This subsystem transmits the earthquake wave data observed by seismometer monitoring network to the subsystem for earthquake motion data acquisition in real-time.
As described in the concept of system, this system assumes to utilize existing seismometer monitoring networks. Such networks supposed to be used in this research are the k-net (maintained by NIED) and the satellite communication earthquake observation telemetering system (maintained by national universities and Japan Meteorological Agency, etc.).
This subsystem(SS-1) has the function to transmit the earthquake wave data by k-net (non-real-time seismometer monitoring network) to subsystem for earthquake motion data acquisition(SS-2) in real-time by using real-time transmission processing program. The seismometer with RTS format is adopted in the transmission to subsystem for earthquake motion data acquisition as the standard format. On the other hand, the satellite communication earthquake observation telemetering system, which is the real-time seismometer monitoring network, adopts WIN format. Therefore WIN format data is converted into RTS format data by using the format conversion program to conform to the standard input of the RTS format.

Subsystem for earthquake motion data acquisition(SS-2)

This subsystem extracts the typical noises from the earthquake wave data transmitted from SS-1. In the noise extraction processing, the characteristics of the data are not impaired. Moreover, this subsystem calculates the

earthquake characteristic value by using the minimum earthquake wave data.
The calculated earthquake characteristic value and the earthquake wave data are transmitted to subsystem for hypocenter and fault parameter estimation(SS-3) and subsystem for earthquake motion parameter estimation(SS-4). Then, these subsystem can promptly estimate the earthquake parameter distribution without using all earthquake wave data.

Subsystem for hypocenter and fault parameter estimation(SS-3)

This subsystem estimates the hypocenter and the fault parameters by using the earthquake wave data transmitted from SS-2. In this research, the methodology, which is capable to estimate the hypocenter parameter (hypocenter position and magnitude) in one minute and the fault parameter (earthquake moment and corner frequency) in three minutes by the workstation of an ordinary specification is developed[Hori, 1998] .

Subsystem for earthquake motion parameter estimation(SS-4)

This subsystem estimates the earthquake motion parameter distribution by using the earthquake characteristic value transmitted from SS-2 .
The following six estimation techniques for earthquake motion parameter distribution are built into this subsystem. Some techniques are capable to consider the amplification characteristic of a local ground motion due to the nonlinear characteristic of the surface soil and irregularity in bedrock (i.e.: so called " earthquake disaster belt" in Hyogo-ken Nanbu earthquake) [Editorial Committee for the Report on the Hanshin-Awaji Earthquake, 1998] .
These techniques have been modulated for each earthquake motion parameter, and can selected an appropriate module arbitrarily in accordance with the needs of users.
Up to the present, the modules of following A) to D), which can estimates the earthquake motion parameter distribution approximately in three minutes after the earthquake, have been developed.

A) An instantaneous correction technique of the predicted earthquake motion parameter distribution by the observed earthquake motion data [Akazawa and Kagawa, 1997]
In this technique, the earthquake motion parameter distribution (distribution of the earthquake characteristics values) by the scenario earthquake, which is identified to cause a strong motion in the applied region, is predicted as the input data. In the prediction of the earthquake motion parameter distribution, an influence of irregular bedrock and a nonlinear characteristic of the surface soil are considered.
When an earthquake occurs, the correction factor is calculated based on the difference between the predicted earthquake motion parameter distribution and the observed earthquake characteristic values. Then, the earthquake motion parameter distribution (seismic intensity, PGA, PGV, PGD, and SI value) is estimated by multiplying the correction factor by the predicted earthquake motion parameter distribution data.

B) An estimation technique by amplification function in surface soil characteristic
In this technique, non-linear characteristic of the surface soil is analyzed by the equivalent linear analytical technique considering the frequency dependency of attenuation. The results of analyses are prepared as the database of amplification function beforehand. The wave data of scenario earthquake used as an input of this analysis is generated by statistical Green’s function method.
When the earthquake occurs, the earthquake characteristic values of the observation point in the applied region is substituted for the amplification function to obtain the earthquake characteristic value on the engineering bedrock below the observation point. Then, the earthquake characteristic value in an arbitrary point on the engineering bedrock is calculated by the space interpolation using some earthquake characteristic values on the engineering bedrock. Finally, the earthquake characteristic values of an arbitrary point on the engineering bedrock is substituted for the amplification function, thus the estimated earthquake motion parameter distribution (seismic intensity(JMA), PGA, PGV, PGD, and SI value) on the surface can be obtained .

C) Earthquake wave estimation technique using fault mode[Ebisawa et al.,1996]
When the earthquake occurs, the hypocenter characteristic is calculated from the fault parameter estimated by subsystem for hypocenter and fault parameter estimation. Next, the propagation path characteristics in the applied region is multiplied by the calculated hypocenter characteristic.
Finally, the acceleration Fourier spectrum is estimated by multiplying the site amplification characteristic of the arbitrary point.

D) Technique by distance attenuation function of earthquake characteristic value
In this technique, the earthquake motion parameter distribution (PGA, PGV, PGD, and SI value) is estimated by using the existing distance attenuation functions.

E) Estimation technique of surface soil characteristic based on the equivalent linear analytical technique [Suetomi and Yoshida, 1998]
In this technique, the earthquake wave data on the engineering bedrock below the observation point is calculated by the equivalent linear analytical technique (the frequency dependency of attenuation is considered) using the earthquake wave data of the observation point in the applied region. Then, the earthquake wave data in an arbitrary point on the engineering bedrock is calculated by the interpolation using the earthquake wave data on the engineering bedrock. Finally, the earthquake wave data on surface is estimated analytically by the earthquake wave data of an arbitrary point on the engineering bedrock.

F) Estimation technique of soil characteristic using the transfer function including the influence of irregular bedrock
In this technique, 2-Dimensional analysis model is constructed in the region where the influence of irregular bedrock is required. The influence of irregular bedrock on the earthquake wave data is estimated using the constructed model by 2-Dimension transfer function. In addition, the influence of non-linear characteristic of the surface soil on the earthquake wave data is estimated by 1-Dimensional transfer function.
When the earthquake occurs, each transfer function is multiplied by the acceleration Fourier spectrum of the observation point in the applied region, and the acceleration Fourier spectrum of an arbitrary point is calculated.

Subsystem for earthquake information transmission(SS-5)

This subsystem transmits the earthquake information (earthquake motion parameter distribution, hypocenter and fault parameter, etc.) to the users through Internet, Facsimile, and others. The homepage to released the estimated earthquake motion parameter distribution within three minutes after the earthquake is being prepared as one example of the information transmission.

Subsystem for earthquake information user(SS-6)

This subsystem has to be maintained by the earthquake information user including other support systems. In this research, it is assumed that the advanced GIS [Hatayama, et. al., 1998], which has the data management function to synthesize the time and space and is capable of the autonomous distributed management, is used in the user environment. The specification in the interface of the seismic emergency information system and the GIS will be investigated .

EXAMINATION OF THE ESTIMATION METHODOLOGIES AND SYSTEM

In order to examine the estimation methodologies and performance of the system, it is necessary to prepare a real-time seismic monitoring network, detailed soil database and the predicted distribution of earthquake motion parameter in the region where the system is applied for the examination. The present status concerning these items are described below.

(1) The region where the system is examined

The region around 30 km of Tokai Research Establishment of JAERI as shown in **Fig.2** was selected as the test field. This region was selected because numbers of soil data, which were used for the aseismic design of nuclear facilities in the Tokai, Oarai and Naka Research Establishments of JAERI, are available. Besides, this area locate on the east coast of middle Japan where the occurrence of earthquake is frequent.

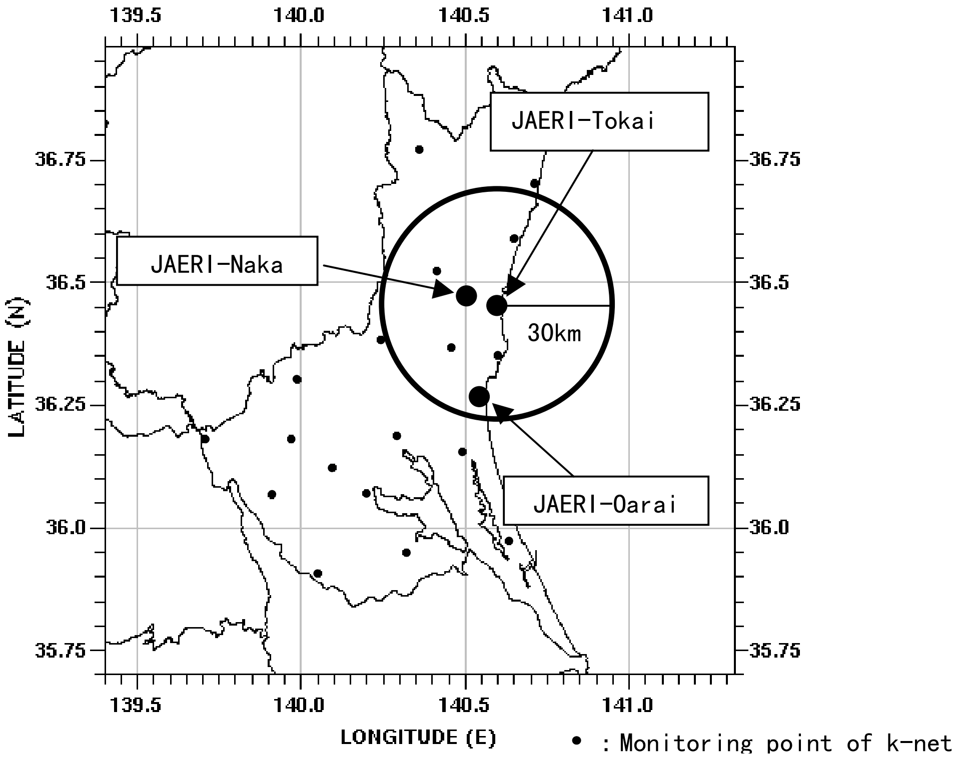

Fig.2 Applied region of seismic emergency information system

(2) Preparation of a real-time earthquake monitoring network

The real-time network which consists of seismometers with the k-net specification and others was prepared for the examination of the system. Seismometer was installed at the each Research Establishment of JAERI. By using the seismometer with the k-net specification, the technique to transmit the time history data of the earthquake motion in real-time is being examined.

(3) Development of the soil database

The soil structure in this region can be divided into two categories, a shallow and a deep soil. Detailed soil database of each soil structure was developed based on the soil data used for the aseismic design of the nuclear facilities of JAERI [Ebisawa, et. al.,1999a].
In the shallow soil, the topography, geography and the stratum configuration were obtained from the surface geological features, the micro-topography division and the geological cross section etc. Based on these information, the shallow soil was classified into 136 models considering the characteristics of stratum configuration and earthquake motion response. On the other hand, the deep soil models which consists of three layers of shear velocity (Vs) 700, 1200, and 3000 m/s were constructed based on soil data.

The region where the system is examined was divided into 500m square mesh. One of 136 soil models was allocated to each mesh in the shallow soil considering the predominant period. Depths of three layer structure were allocated to each mesh in the deep soil. The depth distribution of Vs=1,200 m/s layer is shown in **Fig.3**.

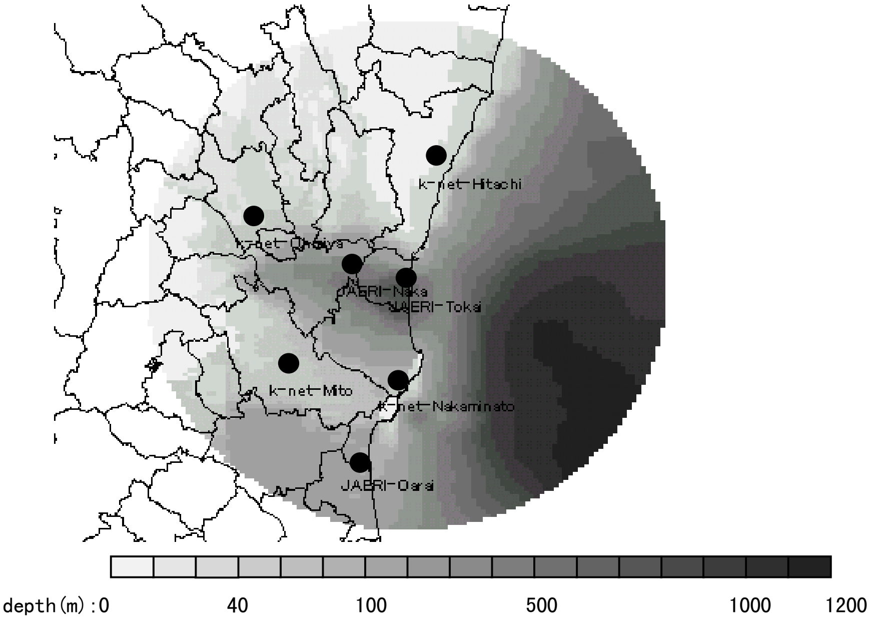

Fig.3 Depth distribution of Vs=1,200m/s layer

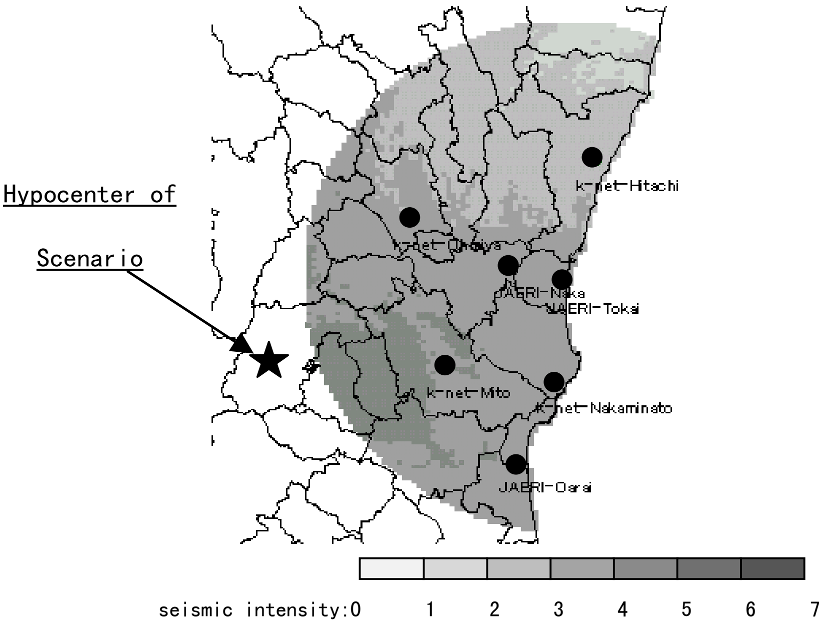

Fig.4 Predicted distribution of earthquake motion (seismic intensity) under the scenario earthquake at the east area of Mt. Tsukuba

(4) Preparation of the predicted earthquake motion and amplification function distributions

For the active fault, lineament and the history earthquake around this region, the predicted distribution of earthquake motion has been obtained by using the above soil data and estimation techniques of strong earthquake motion based on the fault model method. The predicted distribution of earthquake motion under the scenario earthquake of east area of Mt. Tsukuba is shown in **Fig.4**.
The amplification functions were obtained for 136 shallow soil models by the estimation technique of -B and the distribution of the amplification function in this region was established

5. CONCLUSION

In this paper, the progress and present status of the research program on the development of the estimation methodologies and the seismic emergency information system was presented. As described in the paper, the development of the system is being carried out introducing the new estimation methodologies for the parameters of the hypocenter and ground motion incorporating the recent progress in earthquake engineering. The program involves the examination of the estimation methodology and system by preparing the seismometer monitoring network and soil database. As the main parts of the development of estimation methodology and system have been completed, thus the parameter studies on the accuracy and estimating time and applicability of the system will be investigated in the test region of the system.
A part of this research is being conducted as the coordinated program between JAERI and NIED. Useful discussion and suggestion are gained from "Research Advisory Subcommittee on Seismic Information Transmission of JAERI" chaired by professor H. Kameda of Kyoto University. Authors wish to express their gratitude to all who are concerned with this research program.

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