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UrEDAS, URGENT EARTHQUAKE DETECTION AND ALARM SYSTEM, NOW AND FUTURE

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SUMMARY

UrEDAS, Urgent Earthquake Detection and Alarm System, can realize the real-time early earthquake detection and alarm system in the world. There is a local government that has realized a tsunami warning system using real-time estimated earthquake parameters as magnitude and location, distributed by UrEDAS.
On 26th May 2003, the Miyagiken-Oki Earthquake was occurred. It was so large that the maximum acceleration of about 600 Gal was observed along the Shinkansen line and 23 columns of the rigid frame viaducts (RC) were severely cracked. This earthquake occurred on the business hours of the Shinkansen. As expected, coastline "Compact UrEDAS" along the Shinkansen took out the early P-wave alarm before the destructive earthquake motion and the validity of this system was proved for the first time.

INTRODUCTION

UrEDAS is the only real time P-wave alarm system over the world on practical use. It is characterized to be able to process digitized waveform step by step without saving. Amount of procedure does not differs either earthquake occurs or not, so failure because of over load will not occur.
The 2003 Miyagiken-Oki earthquake (Mj 7.1) occurred on 26th May, Compact UrEDAS worked as expected. It was for the first time that the validity of the early warning system was verified under circumstances of big earthquake such as rigid frame viaducts of Shinkansen were damaged.
In this paper, the present condition of P-wave early detection system UrEDAS will be viewed referring to cases at work, also result of test observation where faults exists will be reported. Then new real time data processing system for next generation will be considered.

PRESENT OF UrEDAS AND ITS FUNCTION

There are two types of UrEDAS at present; "UrEDAS" and "Compact UrEDAS".
Function of the UrEDAS is estimating magnitude and location of earthquake by P-wave and issuing the alarm to places which may cause damage. Compact UrEDAS will evaluate whether the earthquake will be

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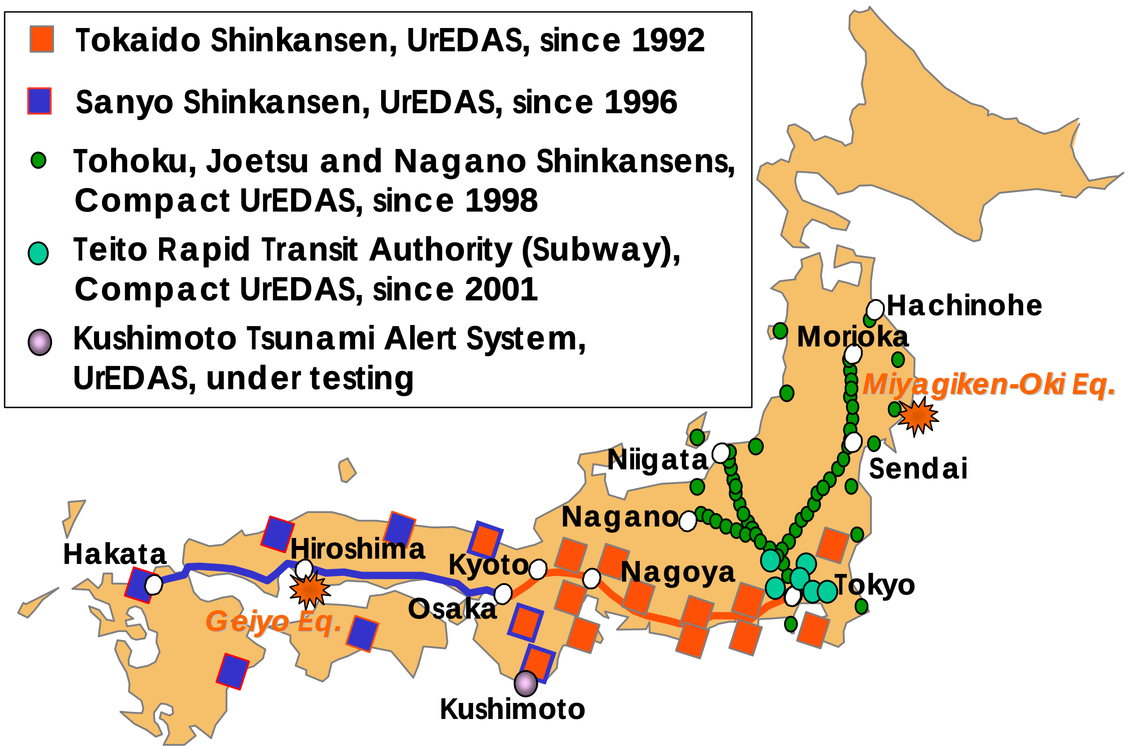


Figure1 The distribution of UrEDAS and Compact UrEDAS in Japan

destructive or not, and will alarm if need. UrEDAS and Compact UrEDAS can issue the alarm in case of earthquakes within range of 200 km and 20 km, respectively.

After the development of prototype UrEDAS in 1985, test observation had been continued. Practical operation was started partly at Omaezaki observatory for Tokaido Shinkansen by limiting its function in 1990. When the Nozomi, new super express, was in operation, fourteen UrEDAS stations were at work officially, with various improvement. At present the new type of UrEDAS took place in 1998 after the former type. **Figure 1** shows the distribution of UrEDAS or compact UrEDAS in Japan.

By the influence of the 1995 Hyogoken-Nanbu Earthquake, Sanyo Shinkansen has promoted the project of installing UrEDAS, and started test operation immediately by using the data of three UrEDAS at west side of Tokaido Shinkansen. Full operation started in November 1996 adjusting five new UrEDAS stations. Along Tohoku and Joetsu Shinkansens and coastline alarm seismometer (45 stations) replaced to Compact UrEDAS by the Spring 1997. Along Nagano Shinkansen which was under construction at that time, Compact UrEDAS was newly installed (six stations), also installed coastline of the sea of Japan to prepare for submarine earthquakes (five stations). Compact UrEDAS has not only P-wave alarm function but also S-wave alarm function which does not need adjustment.

P-wave alarm was on operation since October 1998 after adjusting with suitable earthquake records. Since then Compact UrEDAS has two level alarm function; P-wave alarm and S-wave alarm, which realized quick and accurate warning.

Six Compact UrEDAS stations have been installed for Tokyo Metropolitan subway in March 1998 and started operation first only with S-wave alarm function, and from April 2001 with the P-wave alarm function.

Wakayama prefecture installed one UrEDAS station at Kushimoto, to build tsunami alarm system using function to estimate hypocenter and its magnitude.

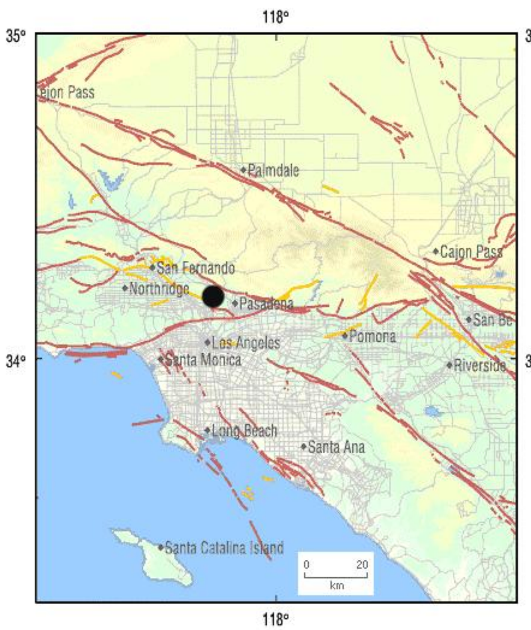
SDR has continued developing for the next generation system. Also UrEDAS has installed at Berkeley (BKS) and Pasadena (PAS), California, with cooperation with University of California and California

Institute of Technology, respectively. This research aims to search for the possibility of UrEDAS alarm against tsunami earthquake at the Pan Pacific region and for the improvement of accuracy of detection at fault area.
And also UrEDAS has installed at Mexico City with cooperating with CIRES, Centro de Instrumentacion y Registro Sismico. CIRES is an organization to observe big earthquake around Acapulco and alarm to Mexico City.

OPERATING SITUATION OF UrEDAS FOR RESEARCH

BKS UrEDAS and PAS UrEDAS

PAS and BKS UrEDAS started observation in July 2000, and in February 2001, respectively. After earthquake detection, these UrEDAS will send e-mail to whom concern in real time. Former type of PAS UrEDAS was at work from September 1993 to August 1999, and observed the 1994 Northridge



PAS UrEDAS

BKS UrEDAS →

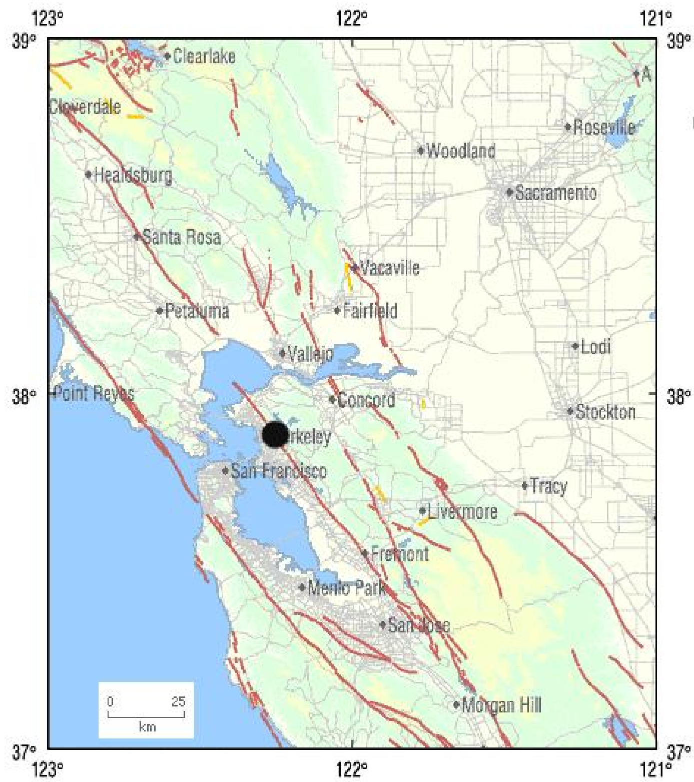
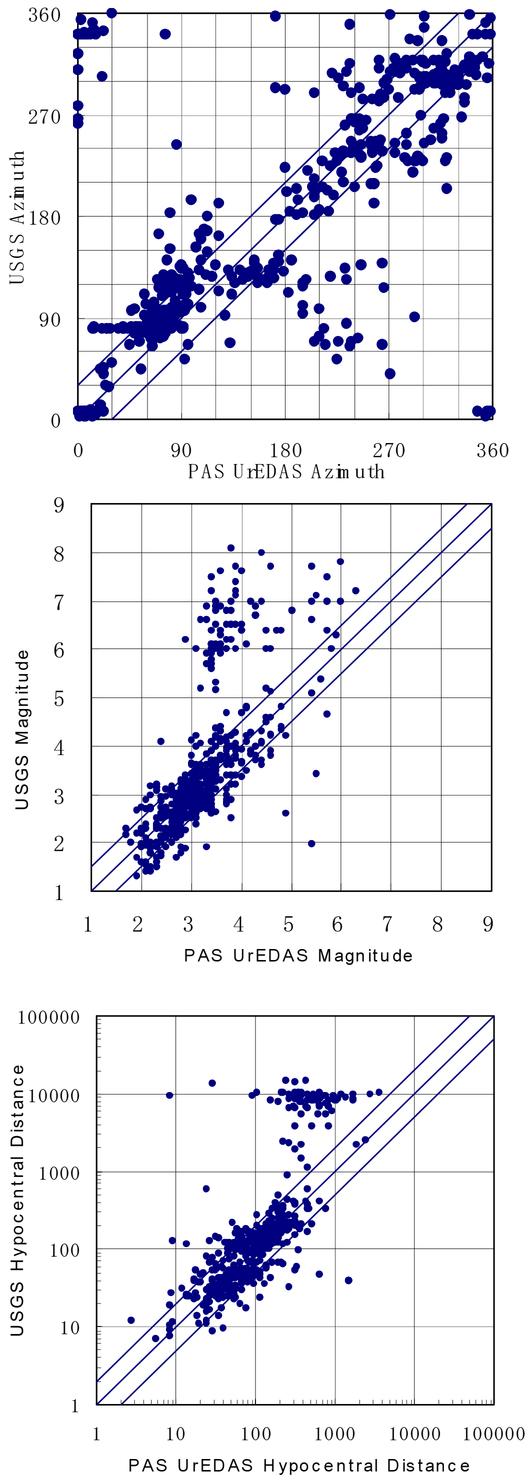


Figure 2 Circumstance of PAS UrEDAS and BKS UrEDAS

Earthquake.
BKS locates just above the Hayward fault while PAS is surrounded by faults (see **Figure 2**). Either station is under bad condition. In spite of the influence of faults, PAS shows better estimate accuracy of focal parameters than BKS, and performance of earthquake detection is effectively at both station.
After this, result of PAS is discussed with all the information delivered by e-mail.
Figure 3a shows the result of comparison between the UrEDAS estimation with recent system parameter and the result of USGS. This shows the error of magnitude is within 1.0, excluding distant earthquake (mainly above M6). Also preliminary hypo-central distance is presumed 0.5 to 2 times excluding distant earthquake over 1000km.



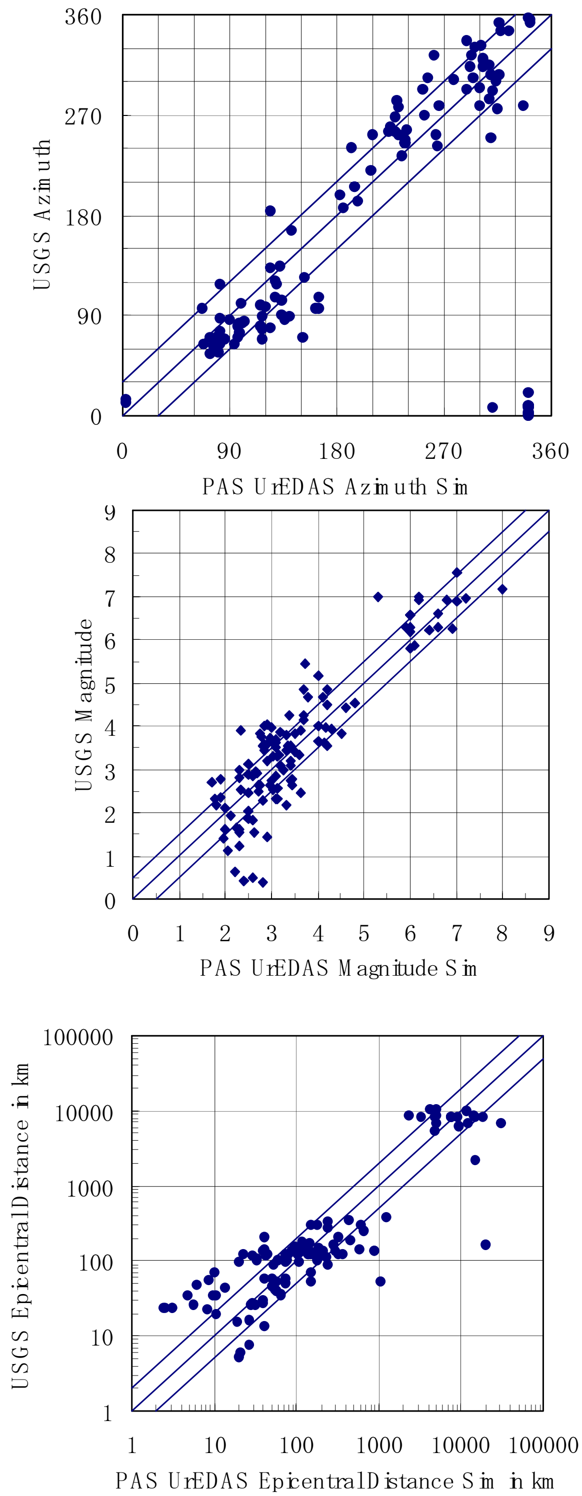


Figure 3a Estimated parameters by PAS UrEDAS in realtime on site

Figure 3b New simulation results using waveform recorded by PAS

Though epicentral azimuth shows error in particular direction which seems to have highly influence of faults, though it shows good result for distant earthquake. This indicates that influence of dislocation remains near ground surface and can be expected the coming direction of distant earthquake motion.

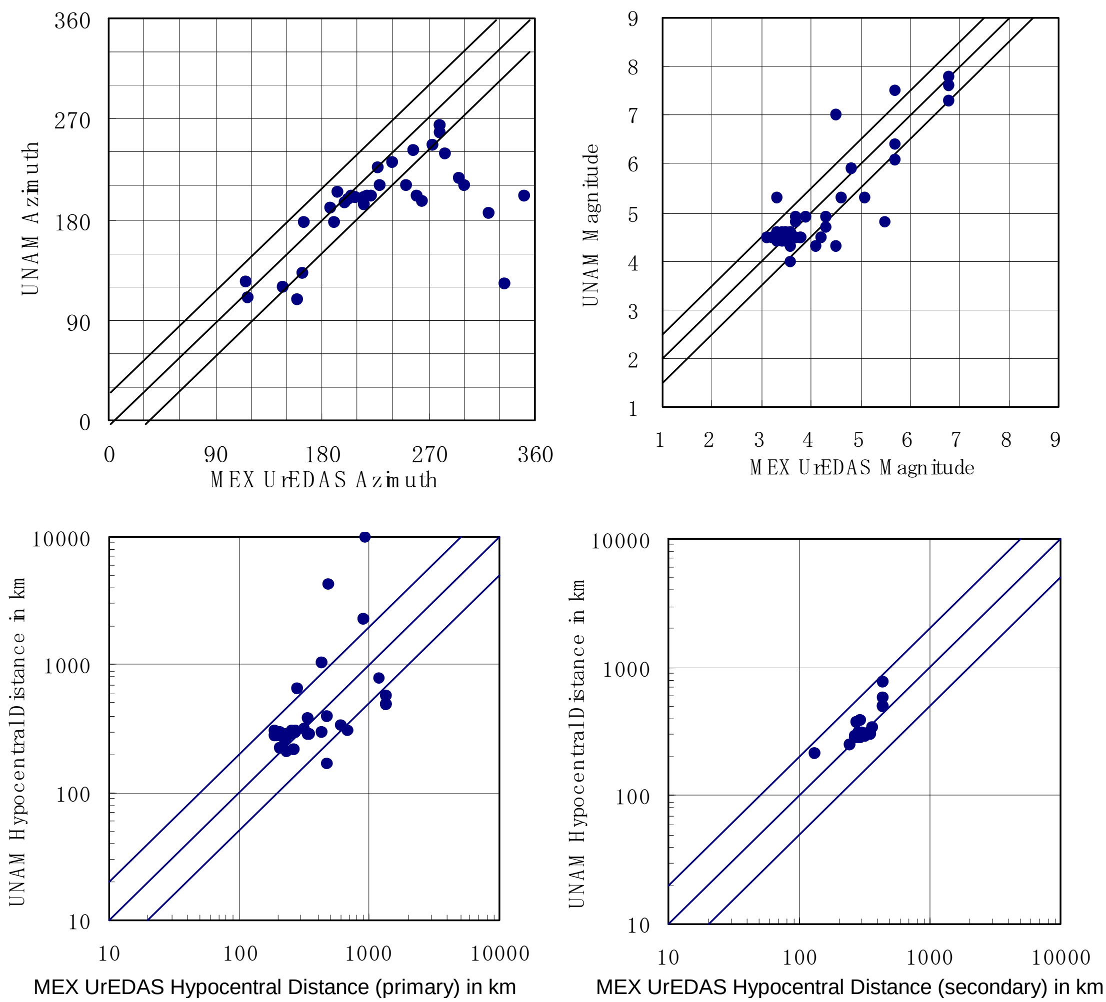


Figure 4 Estimated parameters by MEX UrEDAS in realtime on site

Some of waveform detected PAS UrEDAS and BKS UrEDAS is able to get from internet as cooperative work. **Figure 3b** shows example of simulation for improvement in accuracy using all the waveform recorded in the period between October 2002 and October 2003. Basic technique is almost the same as before [*] for estimating M by initial period and calculating the distance from initial amplitude. But this time P-wave processing time is shorten to one second by three seconds as original. As a result, the accuracy of estimated epicentral azimuth, hypocentral distance and magnitude are improved for the variation of magnitude and distance. Especially the improvement of magnitude estimation using initial motion during one second is interesting that it indicates a big earthquake know by itself to become big from the beginning. Analysis may be improved by the stored data.

MEX UrEDAS

Mexico City (MEX) UrEDAS is installed in a junior high school where strong motion observation site #78 is placed by CIRES. Detected data of MEX UrEDAS will be sent by radio modem to UrEDAS center at CIRES head office and then the information will sent as e-mail to whom concern. This observation started operation in December 2001. Before this test observation and internet connection were operated in different place from February 2000 to November 2001.

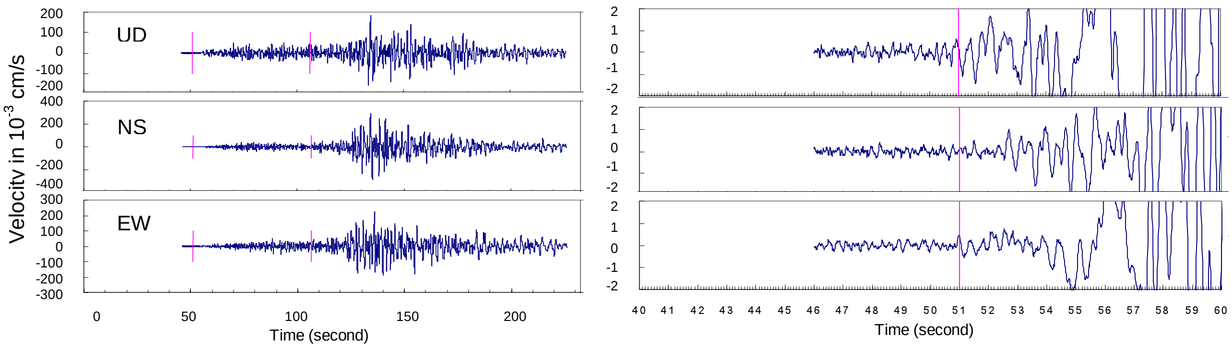


Figure 5 The waveforms of The Colima Earthquake recorded by UrEDAS

Figure 4 shows a result of observation which amplitude is over 0.001 cm/s. This shows that during P-wave, hypocentral distance is estimated distantly, and magnitude is underestimated about 1.0. Epicentral azimuth and hypocentral distance during S-wave are substantially proper.

RECENT EARTHQUAKES DETECTED BY UrEDAS

The Colima Earthquake, Mexico (2003)

The Colima Earthquake occurred at 20:06:36 (Mexican standard time, MST) in January 21st 2003 near Colima about 400km west from Mexico City where UrEDAS was installed. This earthquake caused sever damage near epicentral area. Information from MEX UrEDAS was received at Kunitachi, Tokyo at about 11:19:00 of the 22nd. (Japan Standard Time, JST) as followings,

+Detected time of the earthquake: 22nd 02:07:51 (Coordinated Universal Time, UTC)
+Preliminary estimated focal parameters received at CIRES at 02:07:56, (UTC): Magnitude M6.8, epicentral azimuth 280 degree clock-wise from north, hypocentral distance 232km, depth 134km. Estimated epicenter is located in near the middle point between Mexico City and Colima at this time.
+Secondary estimated focal parameters received at CIRES at 02:08:53 (UTC): hypocentral distance 442km, depth 255km. Magnitude and azimuth are same to preliminary result. Estimated epicenter in final is about 60km northeast from Colima

UrEDAS says, just after the primary wave of earthquake arrived, M6.8 earthquake is occurred in hundreds kilometer west (according to experience, magnitude will be M7.8) Few minute later, when large motion arrived, UrEDAS says epicenter turned out to be near Colima.
Figure 5 shows the waveform recorded by UrEDAS. This figure shows UD, NS and EW components in unit of 0.001cm/s, and indicator at 51 second and 105 second shows detected time of P-wave and S-wave by UrEDAS, respectively.
From this waveform, the first motion was comparatively small, and after 4 seconds the first big P-wave motion arrived. Because hypocentral distance was about 400km, duration of preliminary tremors was about one minute from first information sending to large motion.
UrEDAS has sent the first estimated result to CIRES center three seconds after P-wave detection, and just after the S-wave detection it send secondary information immediately. CIRES system received these information three seconds delay. It was 12 minutes delay in Japan to receive UrEDAS information after the occurrence of the Colima earthquake. It seems to have a large time gap for internet communication, though considering that the arrival of wave motion of earthquake in Japan takes 20 minutes, it is able to

say that information was received before the earthquake motion arrives. Considering of UrEDAS observation result in Japan, it is expected to be accurate information of earthquake parameter and realize accurate tsunami warning system.

The 2003 Miyagiken-Oki Earthquake

The Miyagiken-Oki Earthquake was occurred at 18:24:33 (JST) on May 26th with about 70km depth. Compact UrEDAS at Rikuzentakada near the epicenter has detected this earthquake and immediately issue early P-wave alarm. By the data recorded at Rikuzentakada station of KiK-net, since P-wave was detected at 18:24:44, so it is estimated that P-wave alarm had been issued at 18:24:47. By this alarm, train operation was stopped between Sendai and Morioka before P-wave arrival. Rigid frame viaducts have cracked in northern part of this section.

This was the second damaging earthquake occurred near the Shinkansen line during business hours (the first earthquake was the 2001 Geiyo Earthquake) and the first earthquake for UrEDAS to alarm.

At the time of this earthquake there were eight trains between Sendai and Hachinohe, about 100km north from Morioka, where it had strong earthquake motion over 100 Gal (5HzPGA, see paper #). Fortunately running train in high speed was only two trains, Yamabiko #59 and Hayate #26, others were very low speed or stopping at station. **Figure 6** shows the relationship between the origin time, alarm issued time, damaged area and also the position of trains from time table. If the earthquake occurred 10 minutes thereabout before or after, it had high possibility for train to pass the track on the damaged structure.

Yamabiko #59 just left Kitakami station to north and has stopped immediately by early P-wave alarm. It stopped 3km from the station, and 10km before the damaged structures.

Hayate #26 has passed Iwate-Numakunai station and was heading south by full speed. Earthquake motion of this area was estimated over 300 Gal. Because of running over hard ground or in tunnel, referring to the Geiyo Earthquake, passengers and crew might have not felt the earthquake. Alarm to Hayate #26 was delayed about 10 seconds comparing with the area south from Morioka alerted by early P-wave. So it is estimated that it was running at full speed without noticing the earthquake.

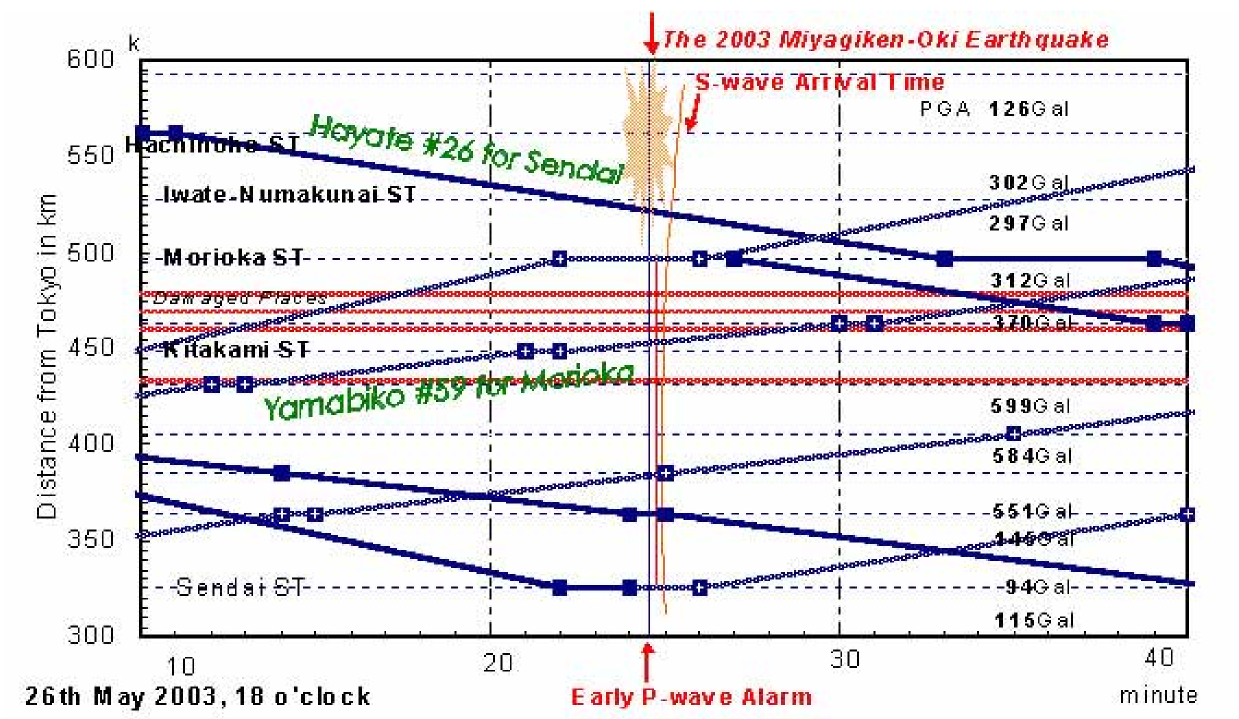


Figure 6 Situation of the Shinkansen when the 2003 Miyagiken-Oki Earthquake from the time table

It shows that people on the running trains have difficulty to notice earthquake motion, thus earthquake alarm from outside is necessary.

And also, when the Geiyo Earthquake occurred many running trains encountered earthquake motion over 300Gal as Hayate #26 at the time of the Miyagiken-Oki Earthquake. Result of investigation of the Geiyo Earthquake shows that trains running at full speed as like Nozomi or Hikari, in high-speed operation, at places such as in tunnel, passengers and crews won't feel the motion. On the other hand Kodama, stopping every station, running at low speed almost arriving to a station, passengers had felt fear that have thought the train will derail. Passengers of this train noticed that it was earthquake by looking outside and saw destruction of roof or shake of electric wire.

When the Geiyo Earthquake occurred seismometer along the railroad near the focal area had alarmed immediately and UrEDAS far from focal area didn't alarm.

Yamabiko #59 just left Kitakami station and other trains at station might have felt larger motion than the Geiyo Earthquake though details are unknown. How the passengers felt in area where large motion attacked is worthwhile to analyze.

REALTIME EARTHQUAKE DISASTER PREVENTION IN FUTURE

Information system causes insufficiency in occurrence of big disaster. As bigger the information system gets weaker it is to disasters.

It is important to be equal to the occasion, thus rational and positive consciousness of disaster prevention is required. Equipment for disaster prevention, firm and reliable system which work certainly is also required. Therefore building systematic and individual system that works with high accurate priority is more significant than building enormous system for disaster prevention. Turnover of mind "disaster prevention system" to "systematic disaster prevention" is required.

Firm, inexpensive and reliable system for disaster prevention should be built such as early warning and indicating evacuation even if rack of some accuracy. It is expected distributing many of these equipment will be urged, cooperating with existent information system to reduce damage by disaster.

CONCLUDING REMARKS

This paper has viewed the present condition of UrEDAS the only realized system for early warning. To apply the UrEDAS not only for railway system but also for other field not only toughness and reliability but also easy to get it would be required than as now.

Also alarm seismometer or instrumental intensity meter is expensive for everyone. But the concept of acceleration and seismic intensity should be known widely. Rational and immediate action for prevention of disaster will be possible, if exact vibration sense against earthquake motion could be produced on their each sense. Then earthquake motion should be expressed as fixed quantity such as temperature, humidity or time.

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