Evaluation of the accuracy of back-azimuths estimated in real-time by using single station record

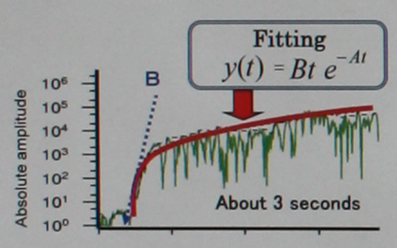
Shunta Noda[1], Shinji Sato[1],
Shunroku Yamamoto[1], Masahiro Korenaga[1],
and Kimitoshi Ashiya[1]

1, Railway Technical Research Institute

1.Introduction

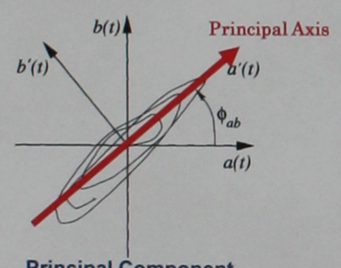
- Recently, the technology of earthquake early warning system has achieved an amazing development.
- The earthquake early warning system has some difficult problems.
  One of the important problems is how to estimate the location of hypocenters (epicenters) in real-time.
- In the Earthquake Early Warnings of JMA or Earthquake early warning system for Shinkansen, in case an earthquake is detected only at a single station,
  B-Δ method and Principal Component Analysis (PCA) are used to estimate the epicentral distance and the back-azimuth, respectively.

Epicentral Distance



B-Δ method (Odaka et al., 2003)

Back-azimuth



Principal Component Analysis (PCA)

- PCA estimates the back-azimuths by using the principal axis of the first motion (1-2 seconds) of P wave.
- In this study, we evaluated the accuracy of the back-azimuths estimated by PCA.
- And we tried to improve the accuracy.

2.Data

- 2,415 records (K-net), 1996 – 2008
- Epicentral distance ≦ 300km
- JMA instrumental seismic intensity ≧ 3.5
- P wave arrival times → Automatically picking
- Band-pass displacement wave records
  → Calculated from the recurrence formula filter
- 1.1 seconds data from P wave arrival time
  → This time window is a parameter used in the present warning system.

3.Result

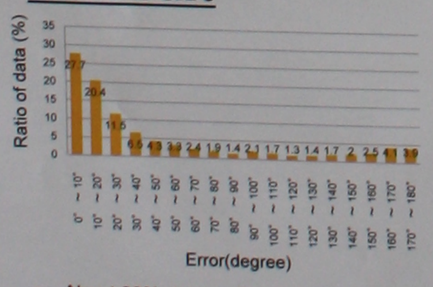


Fig.1
Errors in case that the time window is 1.1 seconds.

Error in this case

$$Error = |Ae - At|$$

$$-180° \le Ae - At \le 180°$$

Ae = Back-azimuth estimated by PCA
At = Back-azimuth calculated from the JMA hypocenter

- About 60% data → Errors are ranging from 0 to 30 degrees.
  → We can say the method used in the present warning system has good precision.
- There are relatively many data the errors are ranging from 160 to 180 degrees.
- Average of the errors is 46.8 degrees.

4.Improvement of the accuracy

- We try to improve the accuracy of back-azimuths estimated from PCA by changing the time window.

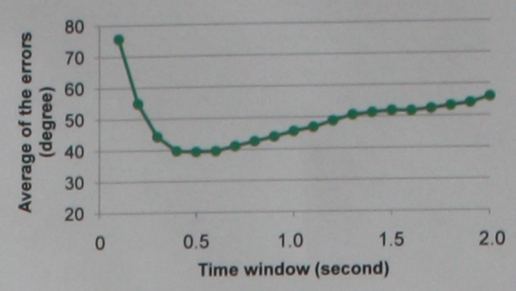


Fig.2
Averages of the errors calculated from changing the time window.

- Minimum of the averages is 39.4 degrees (Time window = 0.5 seconds)

The accuracy improves about 16%, compared to the case that the time window is 1.1 seconds.

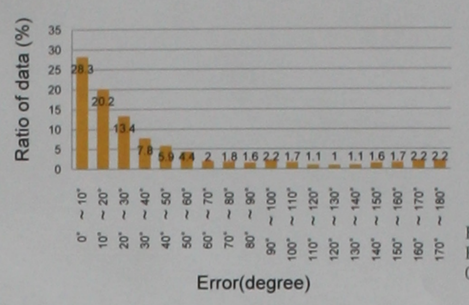


Fig.3
Errors in case that the time window is 0.5 seconds.

- Short time window (= 0.5 seconds) is better than the long one (= 1.1 seconds).
- A result calculated from the long time window can be influenced by the later scattering wave.
- To reduce the influence of the later scattering wave, we use the widths of the first pulse of up-down component as time window.

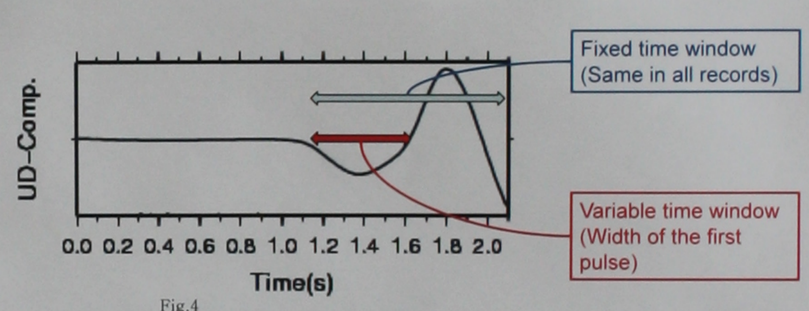


Fig.4
Fixed and variable time window.

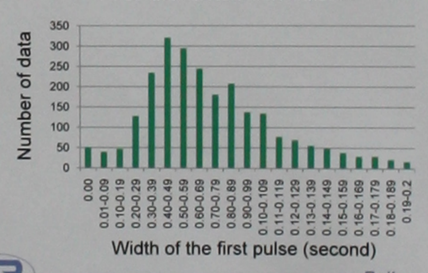


Fig.5
Distribution of the first pulse width. If the width of first pulse cannot be calculated in 2 seconds, it is assumed to be 0.

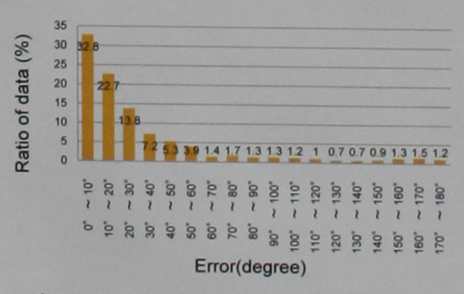


Fig.6
Errors in case that the time window is the width of first pulse. If the width of first pulse were 0, <0.2 and >2.0 seconds, the time window was 0.5, 0.2 and 2.0 seconds, respectively.

- Average of the errors is 31.9 degrees.
- The accuracy improves about 32% and 19%, compared to the case that the time window is 1.1 and 0.5 seconds, respectively.

Table1. Result in this study

Time Window	1.1 seconds	0.5 seconds	Width of first pulse
Average of errors	46.8°	39.4°	31.9°

5.Conclusion

- The accuracy of back-azimuths estimated from single station records on the present warning system has good precision.
- Short time window (about 0.5 seconds) is better than the long one (1.1 seconds).
- For more improvement of the accuracy, we suggest to use the variable time window.
  If we use the width of first pulse as time window, the accuracy improves about 19% in comparison to the case that the best fixed time window is used.

P14 Noda

P-14