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# Time reversal pulse of seismic focus and transition radiation
# 震源のタイムリバーサルパルスと遷移放射

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## 1. Introduction

We analyze the seismic focus vibration from the knowledge of acoustics. Previously, the seismic focus vibration has analyzed by using the time reversal method, and the dynamic model of the seismic focus vibration has proposed[1-5]. This model has verified about four earthquakes larger than M 5 that occurred near Mt. Fuji and the adaptability has verified. Hear, the data of the earthquake that occurred in Suruga Bay at August 11, 2009 is analyzed and the nonlinear radiation from the active fault is shown from a theoretical standpoint.

## 2. Dynamic Model

It is important in the prospect of an earthquake in the near future to know the movement of an active fault. The time reversal process is executed to the P wave signal received at an observation station and the time reversal pulse (TRP) formed at the center of an earthquake position is obtained. The TRP corresponds to an equivalent acoustic source to which the center of an earthquake emits. To clarify the origin of the azimuthal dependence of the TRP, the frequency spectrum of the TRP to the azimuth is obtained. The maximum amplitude frequency largely rises to the azimuthal change from the west to the east and it descends thereafter. The rise of the frequency originates in the high-speed movement of the crack in the center of an earthquake. The head part only of the signal received in Nishiizunishi observation station located in the moving direction expanded. The head of those received in adjacent Ito and Kawazu is almost smooth. Nishiizunishi is a specific observation station to this earthquake. When the progression rate of the crack in an active fault becomes close to the P wave speed, the head of the signal grows in this manner. That is, it is thought that the parametric effect to which the pressure caused by the crack is added cumulatively is caused. The dynamic model shown in Fig.1 is derived from these results. The point where the beam emitted from the active fault reaches surface of the earth is called a parametric spot (PS) and the expanded head is called a parametric head (PH).

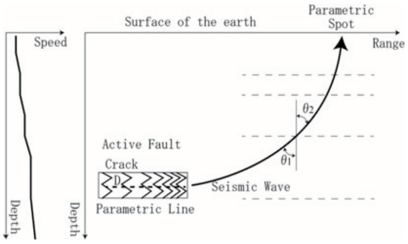

Fig.1 Dynamic model of focus vibration

The dynamic model shown in **Fig.1** is derived from these results.

## 3. Nonlinear radiation of seismic focus

To verify the above mentioned model, the parametric spot that the feature of the model is proven is obtained for four earthquakes that occurred near Mt. Fuji. The vibration in the center of an earthquake, that is, the TRP is obtained by using the time reversal method. The parametric spot is obtained from those azimuthal dependences. All of the four earthquakes have the parametric spot, and they have suited the dynamic model. However, the formation mechanism of a parametric spot has not been clarified at all. Pavlov et al. have analyzed theoretically the radiation from a nonlinear medium, and derived the equation concerning Cerenkov radiation and transition radiation. Pavlov's theory gives transition radiation as[6],

$$\left\langle \bar{W}_{\omega,\mathrm{n}} \right\rangle^{\mathrm{Tr}} \cong \frac{2\pi\sqrt{\pi}C}{(8\pi)^2} \frac{c\left|F_0\right|^2 \left\langle \varepsilon^2 \right\rangle \ell^3 k^4 M^2}{\sqrt{(1-M^2-2\kappa_k)^2+4\gamma_k^2}} \times \exp\left[-\frac{1}{4}(k\ell)^2\left[\left(\frac{1}{M}-\cos\theta\right)^2+\sin^2\theta\right]\right] \quad (1)$$

Transport rate of the vibration (Mach) and radiation angle (θ) relate to this radiation. Then, the frequency spectrums of TRPs are obtained near Nishiizunishi that is the parametric spot of this earthquake. **Fig.2** is frequency spectrums corresponding to the observation stations in Izu peninsula. The longitudinal axis is the azimuth from the center of an earthquake. The spectrum maximum amplitude frequency, so-called a peak frequency, of Shuzenji is 4 Hz. The peak frequency decreases with an increase in the azimuth, and 1 Hz in Nishiizunishi of the azimuth 86°. The peak frequency increases thereafter up to 3 Hz at

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Minamiizu. Such a variation is aligned as the angle variation of Eq. (1).

## 4. Transition radiation

The constants concerning nonlinear of the active fault are not known. Each constant is assumed here and the radiation characteristic of transition radiation is examined. The angular characteristic in which transport rate (M) of the vibration of the frequency 5 Hz is assumed to be a parameter is shown in **Fig.3.** The radiation has the periodicity of the angle, and the amplitude depends on the value of M greatly. The angular characteristic in which the effective length (km) of the vibration of the frequency 5Hz is assumed to be a parameter is shown in **Fig.4**. The transport rate is M=0.999. The radiation amplitude increases with the increase of the effective length, and the angle period shortens. The angular characteristic in which the frequency is assumed to be a parameter is shown to **Fig.5**. The transport rate is M=0.999, and the effective length is 6 km. The radiation amplitude is periodic in the angle. The radiation amplitude increases with the increase of the frequency, and the period of the angular variation shortens. Therefore, the radiation amplitude becomes a monotonous summation of each frequency component in the angle smaller than 7°. The vertical bar at angle 6° in Fig.5 shows the situation. On the other hand, when the angle becomes larger, it becomes a polarized summation because the period of each frequency is different. This phenomenon suggests the characteristic to which the peak frequency like Fig.2 varies at the angle (azimuth). In order to demonstrate the matching with the theory, it is necessary to know nonlinear constants of an active fault.

## Summary

The dynamic model of the center of an earthquake quake was shown, and the effectiveness was confirmed for four recent earthquakes. In addition, the transition radiation theory and the analytical result are compared to confirm the effectiveness of the dynamic model, and the qualitative coincidence was obtained.

## Acknowledgement

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## References

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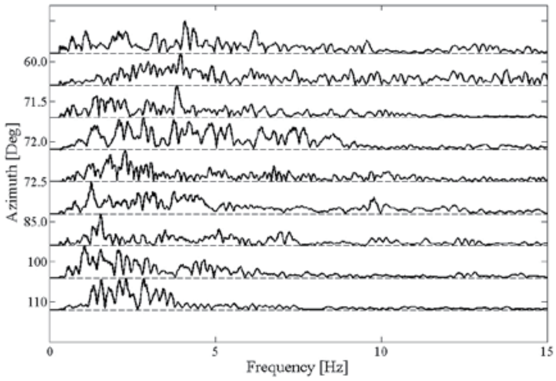

Fig.2 Frequency spectrum of TRP at Izu peninsula.
Uper: Shuzenji, Lower: Minamiizu

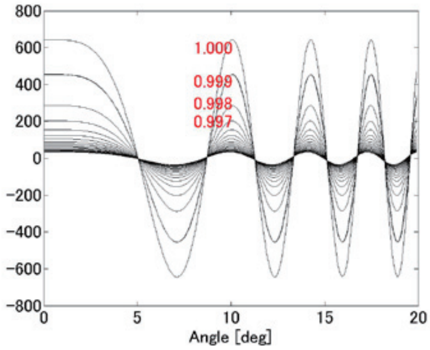

Fig.3 Radiation amplitude as parameter of M.

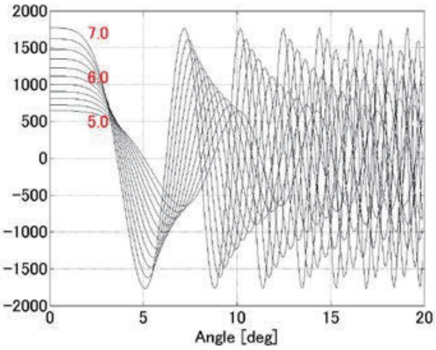

Fig.4 Radiation amplitude as parameter of active length (km).

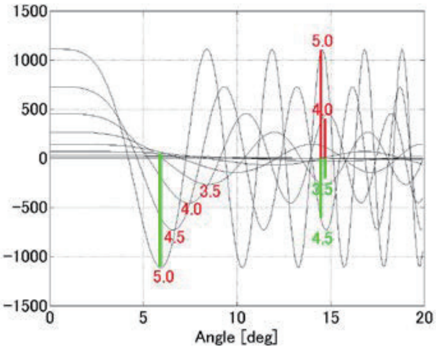

Fig.5. Radiation amplitude as parameter of frequency.

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