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SEMIANNUAL TECHNICAL SUMMARY

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VI. SUMMARY OF TECHNICAL REPORTS/PAPERS PREPARED

VI.1 Seismic source spectra and moment tensors

The quantification of seismic sources (e.g., scalar moment or magnitude), the determination of source size (e.g., corner frequency methods), and the determination of radiation pattern (e.g., fault plane solutions), are procedures which usually proceed separately and use different parts of the seismic spectrum. Of course, the various source parameters are not independent of one another, and they are often related through semi-empirical rules (Kanamori and Anderson, 1975). There would be obvious advantages if source parameters could be determined simultaneously. The seismic moment tensor represents both scalar moment and radiation pattern, but applications are restricted to what may be regarded as point sources. In principle it is possible to remove this restriction by extending the representation to moment tensors of higher degree (Backus, 1977), and as described in the previous semiannual report, in practice it is possible to estimate moment tensors up to degree two (Doornbos, 1982a). At this stage, however, a long-period approximation is still implied, and spectral information above the corner frequency cannot be used in the present procedure.

In a more recent attempt to reconcile the information from long- and short-period data (Doornbos, 1982b) it was shown that when the source spectrum is expanded in powers of frequency, the coefficient of the n'th power is a linear function of the n'th moment tensor:

$$F(\underline{\zeta},\omega) = 1-i\omega\underline{\zeta}^T\underline{F}_{(1)}-\tfrac{1}{2}\omega^2\underline{\zeta}^T\underline{\underline{F}}_{(2)}\underline{\zeta}+\dots \qquad (1)$$

where $\underline{F}_{(1)}$ and $\underline{\underline{F}}_{(2)}$ are the moment tensors of degree 1 and 2, respectively, and $\underline{\zeta}$ is a 4-dimensional slowness vector:

$$\underline{\zeta} = (\gamma_1/c,\ \gamma_2/c,\ \gamma_3/c,1)^T$$

where c is wave velocity and γ_ℓ a direction cosine of the wave. It should be noted that equation (1) gives the moment tensor expansion of a scalar source function $f(\underline{\xi},\tau)$ which is relative to the moment tensor density of the source by

$$\dot{m}_{jk}(\underline{\xi},\tau) \simeq M_{jk}f(\underline{\xi},\tau) \tag{2}$$

and M_{jk} is the moment tensor of degree zero.

The form (1) explicitly shows the low-frequency approximation by moments of low degree, and suggests suitable ways of extrapolation. In extrapolating to higher frequencies the implied spectral assumption restricts the source model to a particular class, and in Fig. VI.1.1 several possibilities are compared on the basis of a typical triangular earthquake source pulse. The models included are among others ω-square:

$$H(\underline{\zeta},\omega) = \{1+\tfrac{1}{2}\omega^2\underline{\zeta}^T\hat{\underline{\underline{F}}}_{(2)}\underline{\zeta}\}^{-1}\exp\{-i\omega\underline{\zeta}^T\underline{F}_{(1)}\} \tag{3}$$

and Gaussian:

$$N(\underline{\zeta},\omega) = \exp\{-\tfrac{1}{2}\omega^2\underline{\zeta}^T\hat{\underline{\underline{F}}}_{(2)}\underline{\zeta} - i\omega\underline{\zeta}^T\underline{F}_{(1)}\} \tag{4}$$

Here, $\hat{\underline{\underline{F}}}_{(2)}$ is measured with respect to the source's 'center of gravity' in space and time $(\hat{\underline{\xi}}_0,\hat{\tau}_0)$, for which $\underline{F}_{(1)} = 0$. The model has 20 parameters, involving moments of degree zero, one and two. Model-dependent constraints can reduce this number to that employed in other methods. The models lead to simple expressions for the displacement field and the total radiated seismic energy, and they can be made to satisfy certain general properties of observed far-field spectra, including the corner frequency shift of P waves with respect to S waves.

Moments of degree zero represent the final static source parameters, which are usually obtained in a point source approximation from long-period data. A mislocation of the source gives rise to moments of degree one. They determine the phase spectrum in the spectral model, and their determination is equivalent to the classical source location problem by travel time analysis. The source's spatial and temporal extent give rise to moments of degree two. They control the spectral bandwidth and its variation with take-off angle and wave velocity, and their determination corner frequency methods of determining source dimensions. Although solutions for the moments of different degree are not independent, it should often be possible to obtain initial estimates of the moments of degree zero (linear inversion), one and two (linear or nonlinear inversion) consecutively, from long- and shortperiod data or more precisely, from data in at least two frequency bands.

Inversion methods based on this model are being developed to obtain estimates of scalar moment, seismic energy, source size and stress drop, from long- and short-period SRO/ASRO data. It is also found that the following points need further study: (1) The presently employed digital SRO response can be small in crucial parts of the excitation spectrum of commonly observed sources (m_b roughly in the range 5-6). (2) Frequency dependence of Q appears to be needed in source retrieval from long- and short-period data. (3) Short-period amplitude anomalies can significantly affect the source estimates. Points (2) and (3) corroborate the results of others.

D.J. Doornbos

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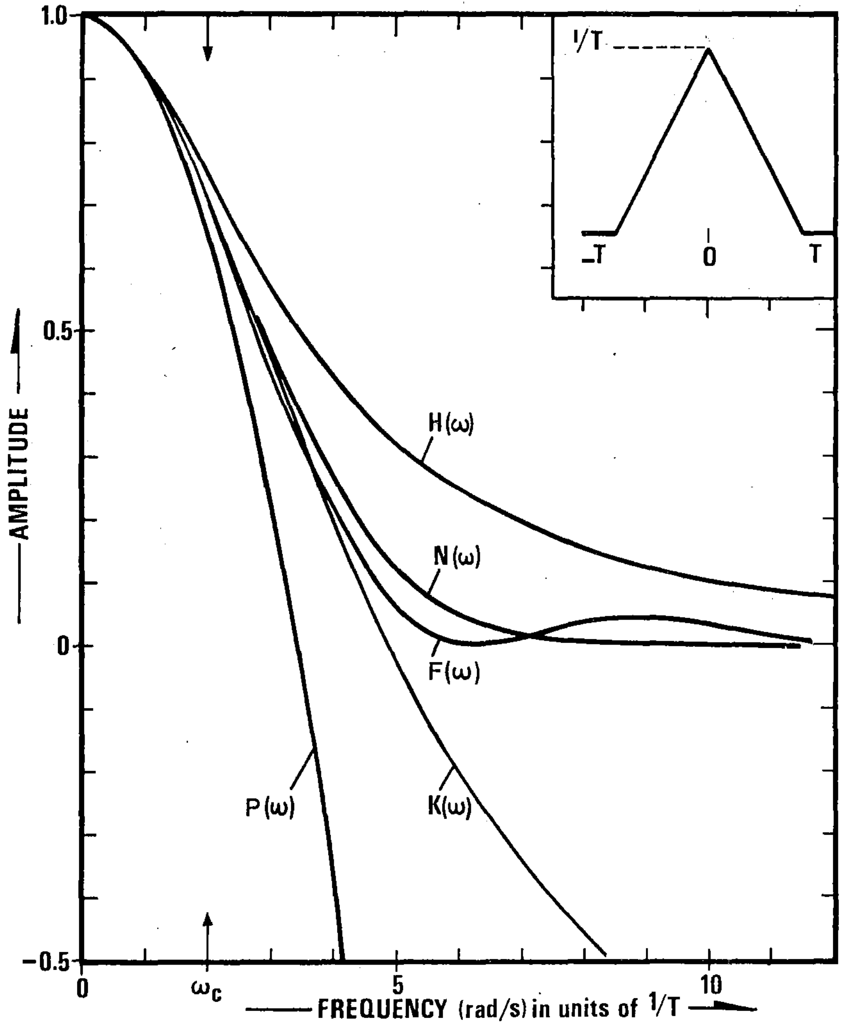

Fig. VI.1.1 Spectral approximations to triangular source pulse (see inset) with amplitude spectrum F(ω) and corner frequency ω_c.
H(ω): ω-square model (eq. (3)); N(ω): Gaussian model (eq. (4)).
P(ω) and K(ω) are a parabolic and a rational approximation, not mentioned in the text.