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Revision of the empirical Green's function method

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1. Introduction

The empirical Green’s function method proposed by Irikura (1986) is one of the most powerful methods for predicting strong ground motions from large earthquakes. The method does make an automated correction of the difference of slip velocity time function between large and small earthquakes. However, there remain some problems to improve it to obtain more accurate ground motions. One is to revise the correction function to get the slip velocity of the target large earthquakes. The other is to be applicable for simulating ground motions at near-fault sites. In this study, we propose revision of the empirical Green’s function method to solve those two problems, correction of slip velocity time function in simulation procedure and application to near-source ground motions..

2. Empirical Green’s function method by Irikura (1986) and correction function of slip velocity

Ground motions $U(R,t)$ from a large event as a target are estimated with a superposition of observed records from a small event used as empirical Green’s functions (Irikura, 1986; Irikura and Kamae, 1994).

$$U(R,t) = \sum_{n=1}^{NxN} (R_0 / R_n) F(t - \xi_n / v_r - R_n / v_s) u(R_0, t) \quad , \qquad (1)$$

where R and R_0 are distance from the large event and that from the small event, R_n and ξ_n are distance from n-subfault to site and that from rupture starting point to n-subfault, and v_r and v_s are rupture velocity and S-wave velocity. Moment ratio of the target and small event is N^3. Then, the fault plane of the target event is divided into N x N subfaults. Here, stress drop is assumed to be constant in the large and small event because equations are simplified. We can easily treat the case where stress drop of the large event is different from that of the small event $F(t)$ in (1) is a function to correct the difference of slip velocity between the target and small event.

In Irikura (1986), $F(t)$ is given as

$F(t) = \delta(t) + D \cdot b_T(t)$. (2)

The first term of (2) is a delta function and the second one is a boxcar function with width *T* and amplitude *D*. The integration of $F(t)$ from *0* to *T* is defined to be *N*. Then *D* is *(N-1)/T* and *T* is *NΔt* (*Δt*: time sampling rate).

Synthetic ground motions by (1) have spectral contents following the ω^2 model in overall shape. That is, the amplitude spectrum of $\tilde{U}(\omega)$ has $N^3 \cdot \tilde{u}(\omega)$ at low frequency end and $N \cdot \tilde{u}(\omega)$ at high frequencies. However, for details the amplitude spectrum of $F(t)$ has significant troughs at frequency *1/T* and its higher harmonics shown in Fig. 1. Resultantly, the spectra of the synthetic ground motions by (1) have troughs at the same frequencies as $F(t)$.

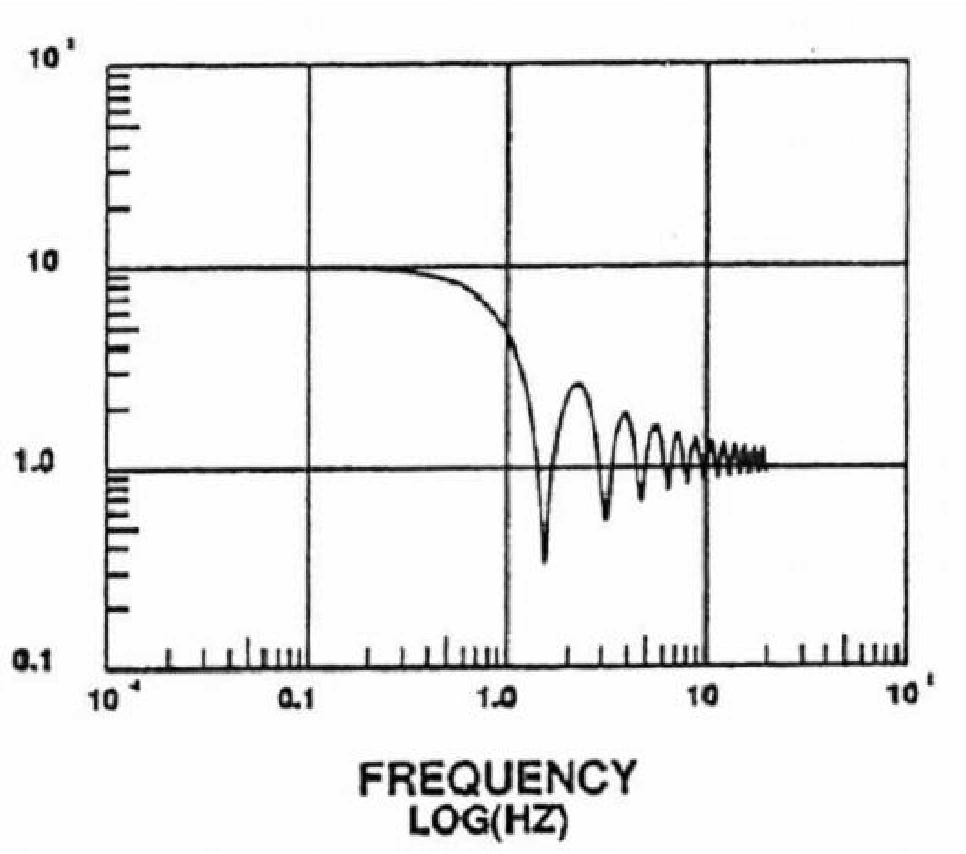

Fig. 1. Fourier spectrum of correction function F(t) [Eq. (3)] for slip velocity in estimating ground motions from large earthquake by Irikura (1986).

The peculiar characteristics of $F(t)$ mentioned above are avoided using a revised function as follows.

$F(t) = \delta(t) + D \cdot e_T(t)$, (3) where $e_T(t)$ is an exponential function defined as

$$e_T(t) = \exp(t/T) \qquad 0 \le t \le T$$

$$e_T(t) = 0 \qquad t \le 0 \quad \text{and} \quad t \ge T\,. \qquad (4)$$

where D in (3) is defined the same as (2), that is, the integration of $F(t)$ from *0* to *T* is *N*.

The amplitude spectrum of $F(t)$ given by (3) has less troughs at frequency *1/T* and its higher harmonics shown in Fig. 2. Therefore, the synthetic ground motions using the correction function (3) have better spectral shapes following the ω^2 model.

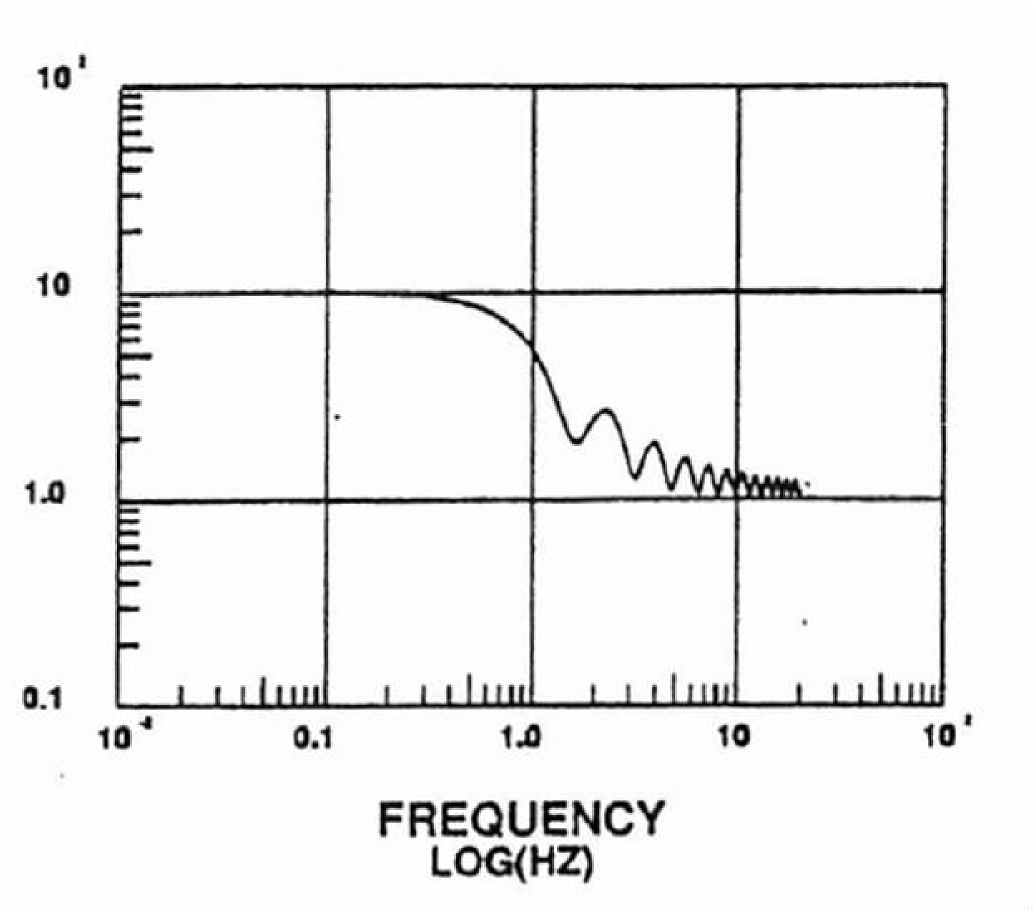

Fig. 2. Fourier spectrum of revised correction function F(t) [Eq. (3)] for slip velocity proposed in this study.

3. Application to simulation of ground motions at near-fault sites

The empirical Green's function method has successfully applied in simulating strong ground motions from a large event even using observed records of just one or two small events. The records are used as the empirical Green's functions over the fault plane of the large event by correcting only attenuation effects due to difference in distance from each subfault to site. One of problems in simulating near-fault ground motions from the large event is that the geometrical spreading factor $1/R_n$ (R_n: distance from n-subfault to site) at near-fault sites becomes unrealistically large as R_n is close to 0. Actually, the attenuation-distance curves of peak ground motions are saturated at near-fault distances even for relatively small events with magnitude 4 to 5 often used as the empirical Greens functions for large earthquakes with more than magnitude 7 (e.g. Cambell, 1997).

Practically, the attenuation-distance curves are approximately given to be $1/(R_n + R_a)$, where R_a correspond to source radius of the small event. We can simulate near-source ground motions from the large event by replacing (R_0 / R_n) in (1) with $R_0 /(R_n + R_a)$.

References

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