

Frequency Dependent Attenuation of High Frequency P and S Waves in the Upper Crust of Garhwal, Himalaya

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Summary

Attenuation properties of the crust around Garhwal seismic zone are studied by estimating the frequency dependent Q_a and Q_b using extended coda normalization method. Seven local earthquakes have been used for this purpose. The mean values of Q_a and Q_b show a dependence on frequency in the Garhwal region. The average frequency dependent relationships ($Q=Q_0f^n$) estimated for the region are: $Q_a = 37f^{1.06}$ and $Q_b = 63f^{1.03}$. The estimates of attenuation parameters obtained in the present study are found to be consistent with the similar relationships obtained for other regions. The outcome of this study is useful in estimating the seismic hazard of the region.

Introduction

The attenuation of seismic waves by estimating the quality factor, Q , has been well studied for the various regions of the world. Aki (1980) first obtained the frequency dependent Q_b for Kanto area, Japan using the coda normalization method. Sato & Matsumura (1980) applied this method to a data set of deep borehole observation. The Q_s has been estimated from the array analysis of strong motion data (Kato et al., 1991; Takemura et al., 1991, Kinoshita, 1992). Yoshimoto et al (1993) has proposed a new method for the simultaneous measurement of Q_a and Q_b by extending the coda normalization method. There are few studies which simultaneously estimated the frequency dependent Q_b and Q_a in the world (e.g. Hough et al., 1988; Masuda 1988; Campillo & Planet, 1991). In the proposed research also the extended method of coda normalization technique is applied to estimate the Q_b and Q_a simultaneously for Garhwal region. Simultaneous estimation of Q_a and Q_b using the extended coda normalization method on local earthquake data for any Indian region has not been reported so far in the literature. The estimation of coda- Q and Q_b are available for Indian regions (Gupta et al., 1995; Gupta and Ashwani, 1998, Gupta et al., 1998; Gupta and Ashwani, 2002).

Study area

The region selected for the present study constitutes southwestern part of the Himalaya. The Himalayan range is the highest mountain range in the world. Here the interplate seismic activity between Indian and Eurasian plate (Nakata, 1989), which is due to convergence

of Indian plate with the Eurasia plate. The region is characterized by the presence of many tectonic features like MBT (Main Boundary Thrust), MCT (Main Central Thrust) along with some local tectonic features like South Almora Thrust and North Almora thrust. The MBT and MCT are the major boundary thrusts, exist through the entire length of the Himalaya. This greatest mountain range i.e. Himalaya is divided into three subgroups they are higher Himalaya, sub Himalaya and lesser Himalaya. The higher Himalayan subgroup made up of central crystalline gneisses and granites, sub Himalaya comprised of folded and faulted Siwalik mollase sediments and lesser Himalaya constituted with Palaeogene and metamorphosed belts of thrust sheets (Valdiya, 1988).

Method

Determining the frequency dependent quality factor, Q , the attenuation studies in the Garhwal region are done for P and S waves using the coda normalization method (Aki, 1980). This method is based on the idea that coda waves consist of scattered S waves from random heterogeneities in the Earth (Aki, 1969; Aki & Chouet, 1975; Sato, 1977). The spectral amplitude, $A_c(f, t_c)$, of the coda at a lapse time t_c can be written as (Aki, 1980):

$$A_c(f, t_c) = S_s(f)P(f, t_c)G(f)I(f) \quad (1)$$

where f is the frequency, $S_s(f)$ is the source spectral amplitude of S waves, $P(f, t_c)$ is the coda excitation factor, $G(f)$ is the site amplification factor and $I(f)$ is the instrumental response. The spectral amplitude of the direct S wave, $A_s(f, r)$ can be expressed as



$$A_s(f,r) = R_{qf} S_s(f) r^{-g} \exp(-pfr/Q\beta(f) V_s) G(f,y) I(f) \quad (2)$$

where R_{qf} is the source radiation pattern and g denotes the geometrical exponent. $Q\beta(f)$ is the quality factor of S waves, V_s is the average S wave velocity and y is the incident angle of S waves.

On dividing equation (2) by equation (1), taking logarithm and simplifying, we get (Yoshimoto et al., 1993):

$$\ln[A_s(f,r)g/A_c(f,tc)]_{\bar{r} \pm Dr} = -pfr/Q\beta(f) V_s + \text{const}(f) \quad (3)$$

where $\ln[A_s(f,r)g/A_c(f,tc)]_{\bar{r} \pm Dr}$ represents the average for a hypocentral distance range $r \pm Dr$. The above equation is obtained under the assumptions that the contribution of R_{qf} disappears by averaging over many different focal plane solutions and the ratio $G(f,y)/G(f)$ becomes independent of y by averaging over many earthquakes (Yoshimoto et al., 1993). The quality factor for S waves can be obtained from the linear regression of $\ln[A_s(f,r)g/A_c(f,tc)]_{\bar{r} \pm Dr}$ versus r by means of a least square method. Using a similar equation the quality factor for the P -waves can be obtained (Yoshimoto et al., 1993).

$$\ln[A_p(f,r)g/A_c(f,tc)]_{\bar{r} \pm Dr} = -pfr/Q\alpha(f) V_p + \text{const}(f) \quad (4)$$

The quality factor for P waves can be obtained from the linear regression of $\ln[A_p(f,r)g/A_c(f,tc)]_{\bar{r} \pm Dr}$ versus r by means of least square method as done for S -waves.

Data

The digital data from Garhwal region related to seven earthquakes is obtained from Department of Earthquake and Engineering, I.I.T., Roorkee. The names, codes and locations of four stations, which are selected for the present analysis, are given below. In fig.1 the epicentral locations of seven events and four stations are shown.

STATION CODE	LATITUDE	LONGITUDE
DHR	30.53	78.76
NNR	30.17	78.29
POR	30.14	78.76
SUR	30.41	78.29

Table-1 is showing the hypocentral parameters of all the events used in the present analysis. Only the vertical component has been used for the present analysis. Each seismogram is filtered using butter worth band pass filter at five different frequency bands. These frequency bands are

given in Table-2. Root mean square technique is applied on these filtered seismograms, which gives RMS amplitude of S -waves, P -waves and Coda-waves. These amplitudes help us to compute the quality factor Q_b and Q_a .

Results

Quality factors for P and S -waves estimated in the present study have a strong dependence on frequency. As the frequency increases quality factor also increases. The average frequency dependent relationships ($Q=Q_0 f^n$) estimated for the region are:

$$Q_a = 37f^{1.06} \text{ and } Q_b = 63f^{1.03}$$

Station-wise estimation of frequency dependent relations is also calculated. They are given as:

Station code	Relation using P-wave	Relation using S-wave
DHR	$Q_a = 26f^{1.28}$	$Q_b = 46f^{1.16}$
NNR	$Q_a = 35f^{1.12}$	$Q_b = 69f^{0.96}$
POR	$Q_a = 52f^{0.8}$	$Q_b = 74f^{0.95}$
SUR	$Q_a = 33f^{1.02}$	$Q_b = 64f^{1.05}$

Fig-2 is representing the Regression of Amplitude vs Frequency for station DHR. Estimation for Q_a and Q_b is done in the same manner for each station. After that average frequency dependent relation is estimated for the region by taking average of quality factors estimated for each station, which is given above. In the present analysis the Q values estimated are low which show the high attenuation possibilities in the region although the values of Q_a and Q_b show strong frequency dependence.

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Sr.No.	Date			O.T.			Latitude	Longitude	Depth	Magnitude
	D	M	Y	H	M	S				
1.	29	03	89	10	59	08.57	30.72	78.86	13	2.41
2.	02	04	89	10	38	59.13	30.31	79.21	20	3.16
3.	12	04	89	17	39	21.62	30.74	78.33	12	3.03
4.	19	04	89	04	39	01.92	30.18	78.65	04	2.92
5.	12	06	89a	12	43	48.23	30.87	78.33	14	3.08
6.	12	08	89b	19	50	05.04	30.16	78.72	09	2.89
7.	18	12	90	08	07	34.93	30.44	78.91	03	4.85

Table-1: Hypocentral parameters of seven local events.

S.No.	Low cut-off	Central frequency	High cut-off
1	1	1.5	2
2	2	3	4
3	4	6	8
4	8	12	16
5	12	18	24

Table-2: Five sets of central frequencies used including Low Cut-off and High cut-off.

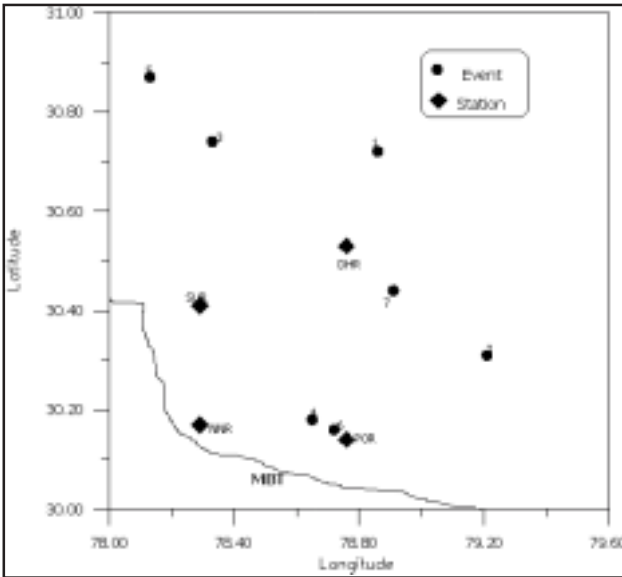


Fig. 1: Epicentral location of events and stations.

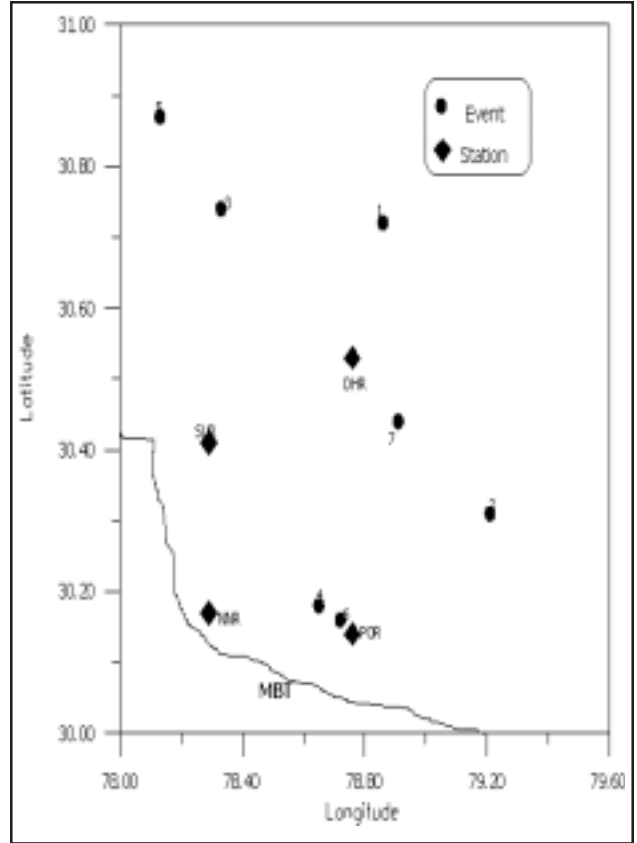


Fig. 2: Regression of Amplitude vs Frequency for station DHR. Also the estimation of quality factor for P and S waves is shown for each central frequency.

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