

The Effect of a Dipping Layer on the Stack Attenuation of Seismic Reflected Signals.

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ABSTRACT

In the Common Depth Point (CDP) reflection technique for seismic exploration, the presence of a dipping layer causes a distribution of reflection points between the sources and receivers. The effect of these displacements on the stack attenuation has been calculated. Theoretical curves of the amplitude response of the straight stacks of three, four, six and twelve fold coverage in the frequency domain are presented for various angles of dip at depths of 2000 m, 3000 m, and 4,800 m. The graphs show that the attenuation of the wavelets increase with increasing dip and depth.

(Keywords: seismic reflection, common depth point, CDP, dipping layer, straight stacks, amplitude response)

INTRODUCTION

A seismic signal must provide good reflection signal-to-noise ratios at all times of interest. (Schneider, 1978). Unfortunately, seismic sources are weak and the objective of the common depth point compositing or stacking is to increase signal-to-noise ratios to a level sufficient to ensure reliable identification of primary events by way of attenuating multiple reflections in addition to random noise. The common depth point field procedure is essentially the shooting of an expanded seismic reflection profile to give several reflection recordings from a common sub-surface reflection area (Figure 1). The reflection coverage may be 3-fold, 4-fold, 6-fold or 12- fold coverage.

For the 4-, 6-, and 12-fold sub-surface coverage geometry, a 24-detector station spread was used. But in the case of the 3-fold coverage a 12-detector station spread was used. The shot is at the end of the spread and the stations are 66 m

apart so that the spread is from zero to 1,533 m in the case of the 4-, 6-, and 12-fold coverage while it ranges from zero to 733 m in the case of the 3-fold coverage.

The detector spreads and shot points are advanced together by two stations for successive recordings in the case of the 3-fold coverage. In the case of the 4-fold coverage the detector the detector spread and shot points are advanced together by three stations, for the 6-fold coverage by two stations and for the 12-fold coverage by one station for successive recordings.

In the common depth point (CDP) reflection technique for seismic exploration (Mayne, 1962), the presence of a dipping layer produces a distribution of reflection points. These displacements have been calculated and found to be significant (Osagie, 2011). The purpose of this paper is to further determine the effect of these displacements on the stack attenuation of the reflected signals for various fold coverage, angles of dips and depths.

In this investigation, we have summed signals of the same amplitude. But in practice, geometrical spreading decreases the amplitude of seismic waves so that a more exact calculation would take account of this fact. Also, the effect on the amplitudes due to anelasticity have been neglected.

The Amplitude Response for Straight Stacks

The 12-fold coverage will be taken as a typical example of the stacking procedure. Suppose a signal $g(t)$ reflected at the point R^1 instead of the point R arrives at the geophone G_{23} (Figure 1). Let the Fourier transform of $g(t)$ be $G(\omega)$, where $G(\omega)$ is in general complex.

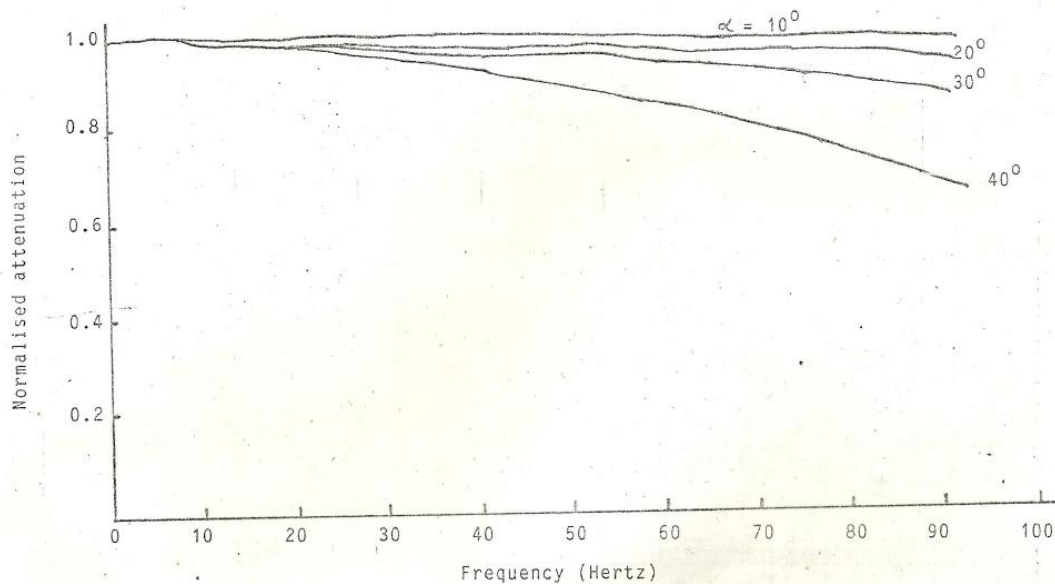


Figure 1: 3-Fold Straight Stack Response at Depth of 4,800 m.

Suppose another signal $g(t - \Delta t_1)$ which is identical to $g(t)$ arrives at G_{21} where Δt_1 is the time delay in arrival and it is the move-out difference between the signals at G_{23} and G_{21} . The same reasoning applies to the other signals on G_{19} , G_{17} , G_{13} and so on (Rietsch, 1980).

The Fourier transform of $g(t - \Delta t_1)$ is $G(\omega) e^{-i\omega\Delta t_1}$ (Papoulis, 1963).

When the signals on these traces are stacked, the result is the following expression:

$$\begin{aligned}
 & G(\omega) + G(\omega) e^{-i\omega\Delta t_1} + G(\omega) e^{-i\omega\Delta t_2} + G(\omega) e^{-i\omega\Delta t_3} \\
 & + G(\omega) e^{-i\omega\Delta t_4} + G(\omega) e^{-i\omega\Delta t_5} + G(\omega) e^{-i\omega\Delta t_6} + \\
 & G(\omega) e^{-i\omega\Delta t_7} + G(\omega) e^{-i\omega\Delta t_8} + G(\omega) e^{-i\omega\Delta t_9} + G(\omega) \\
 & e^{-i\omega\Delta t_{10}} + G(\omega) e^{-i\omega\Delta t_{11}} \\
 & = G(\omega) + \sum_{j=1}^{11} G(\omega) e^{-i\omega\Delta t_j} \quad (1)
 \end{aligned}$$

Equation (1) is normalized by setting $G(\omega) = 1$ and the function becomes,

$$1 + \sum_{j=1}^{11} e^{-i\omega\Delta t_j} \quad (2)$$

since

$\omega = 2\pi f$ Equation (2) becomes:

$$1 + \sum_{j=1}^{11} e^{-i2\pi f\Delta t_j} \quad (3)$$

Expanding Equation (3) into its real and imaginary terms, the following expression is obtained,

$$1 + \sum_{j=1}^{11} \cos 2\pi f\Delta t_j + i \sin 2\pi f\Delta t_j \quad (4)$$

If the amplitude of the wave form is M , then,

$$M = \left[1 + \sum_{j=1}^{11} \cos 2\pi f\Delta t_j \right]^2 + \left[\sum_{j=1}^{11} \sin 2\pi f\Delta t_j \right]^2$$

$L = \sqrt{M}$ is a measure of the attenuation function (Lee, 1960).

The expressions for the 3-fold, 4-fold, and 6-fold coverage are similar to Equation (5) with $j=1$ to $j=3$, $j=1$ to $j=4$, and $j=1$ to $j=6$, respectively.

In the common depth point (CDP) processing of seismic data, two quantities are basically estimated and assigned to each reflection (Robinson, 1970). These are the stacking or normal moveout velocity and the reflection time

corresponding to zero distance between a shot and the geophone (Gardner, et al., 1974). The specific interest in these quantities is that they are related to the important geophysical parameters such as the interval velocities of layers and the depths, dips and other geometric properties of reflecting horizons.

In the case of a dipping reflector, the moveout difference Δt between two traces recorded at any two locations is obtained by multiplying $1/2TV^2$ by the difference between the squares of the offsets from the source to the two group locations. That is:

$$\Delta t = \frac{1}{2TV^2} [x_p^2 - x_q^2] \sin^2 \alpha$$

where, T is the vertical travel times, V is the velocity of the medium which is assumed to be constant and α is the dip. The normalized attenuation for the 12-fold straight stack at a

depth of 4,800 m for dips of 10° , 20° , 30° , and 40° is presented in Table 1 as an example. However, the various plots of normalized attenuation versus frequency for the 3-fold, 6-fold and 12-fold coverage at depths of 2000 m, 3000 m and 4,800 m are displayed.

There are advantages to stacking in the frequency domain (Equation 5). In fact, the technique employed above of stacking separately the real and imaginary components of the Fourier transforms is exactly equivalent to the time domain stack (Marr et al., 1967). The number of calculations involved in the time domain stacking is the same as the number for the frequency domain stacking. There are two traces (real and imaginary components) to be stacked in the frequency domain but only half of the frequencies need be considered because of the usual symmetry of the frequency response of a real time function (O'Doherty et al., 1971).

Table 1: 12-Stack Normalized Attenuation for Various Angles of Dip.

Frequency (Hertz)	Attenuation at depth 4,800 m			
	10°	20°	30°	40°
5	1.000	0.997	0.987	0.965
10	0.999	0.989	0.949	0.864
15	0.998	0.974	0.887	0.715
20	0.997	0.955	0.806	0.543
25	0.995	0.930	0.711	0.389
30	0.993	0.901	0.607	0.319
35	0.991	0.867	0.503	0.319
40	0.988	0.829	0.410	0.364
45	0.985	0.787	0.340	0.386
50	0.981	0.742	0.305	0.370
55	0.977	0.696	0.307	0.321
60	0.973	0.647	0.330	0.263
65	0.968	0.598	0.358	0.321
70	0.963	0.549	0.379	0.243
75	0.958	0.501	0.386	0.275
80	0.952	0.456	0.379	0.295
85	0.946	0.414	0.358	0.288
90	0.940	0.377	0.327	0.256
95	0.933	0.346	0.292	0.214
100	0.926	0.323	0.258	0.190

CONCLUSION

Figures 1, 2, and 3 show the plots of the amplitude response for 3-, 6- and 12- fold stacks,

respectively, at a depth of 2,000 m. Figures 4, 5, and 6 show their respective plots at a depth of 3,000 m while Figures 7, 8, and 9 show their amplitude response at a depth of 4,800 m.

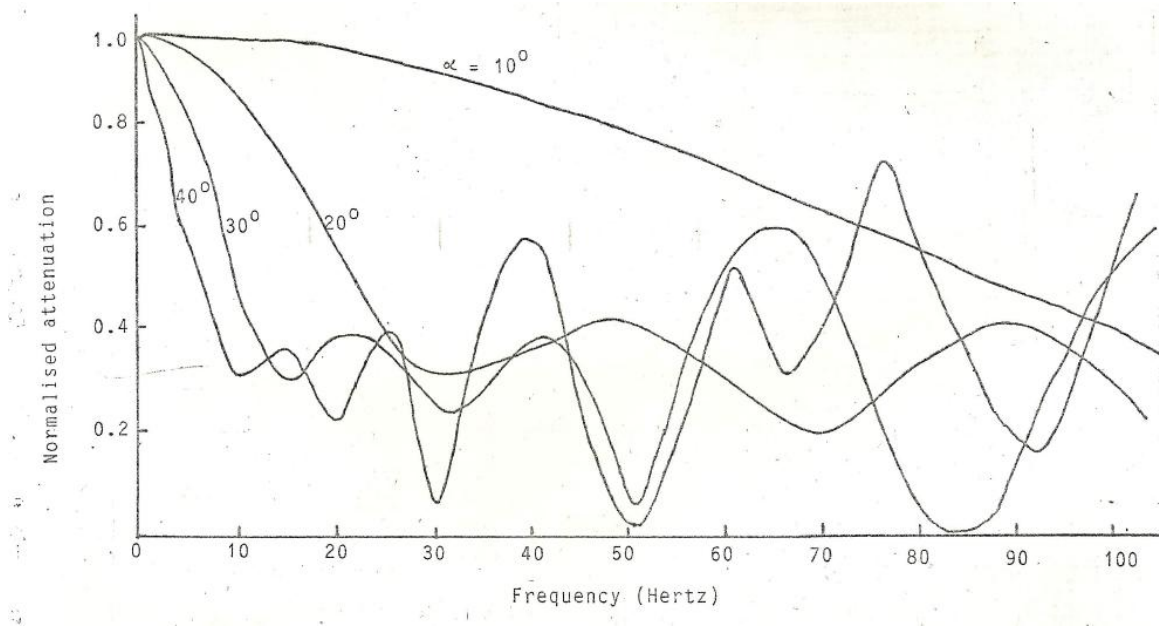


Figure 2: 6-Fold Straight Stack Response at Depth 2,000 m.

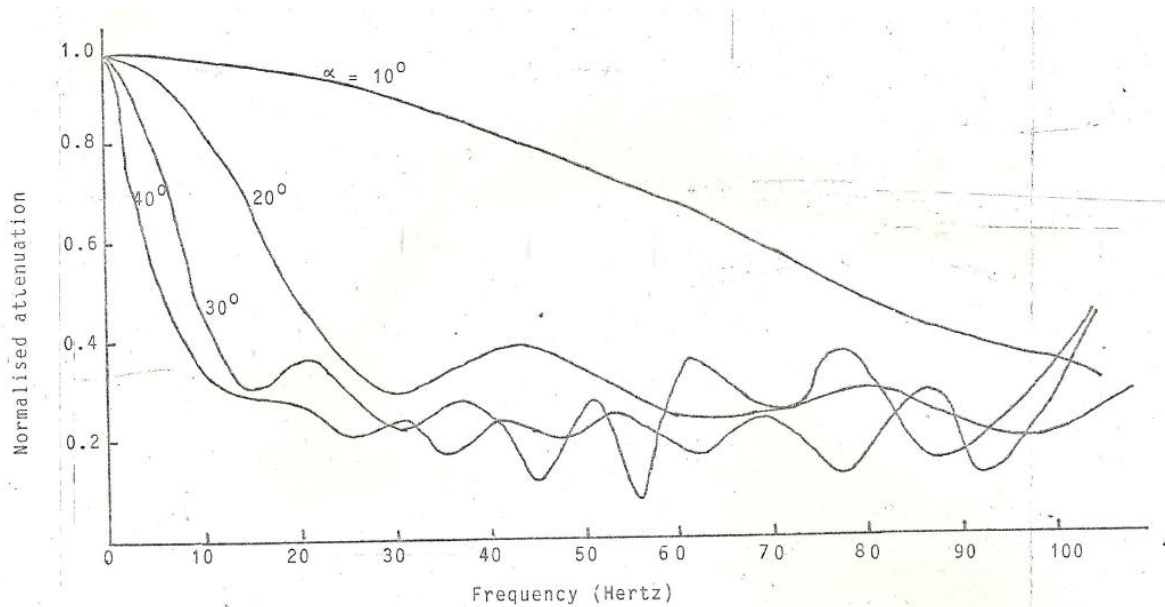


Figure 3: 12-Fold Straight Stack Response at Depth 2,000 m.

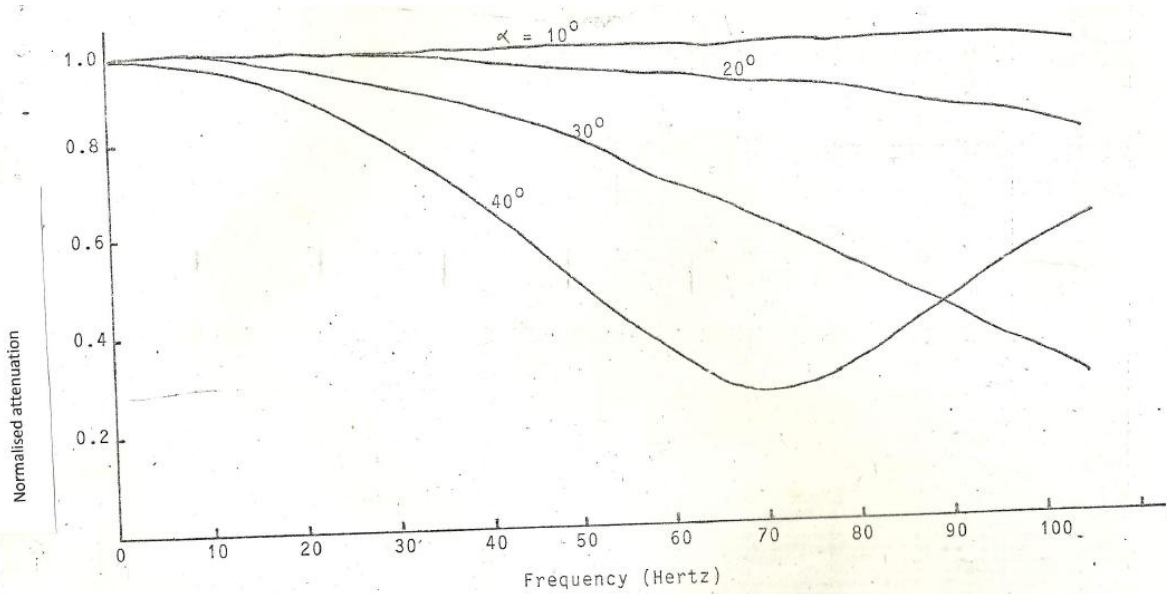


Figure 4: 3-Fold Straight Stack Response at Depth 3,000 m.

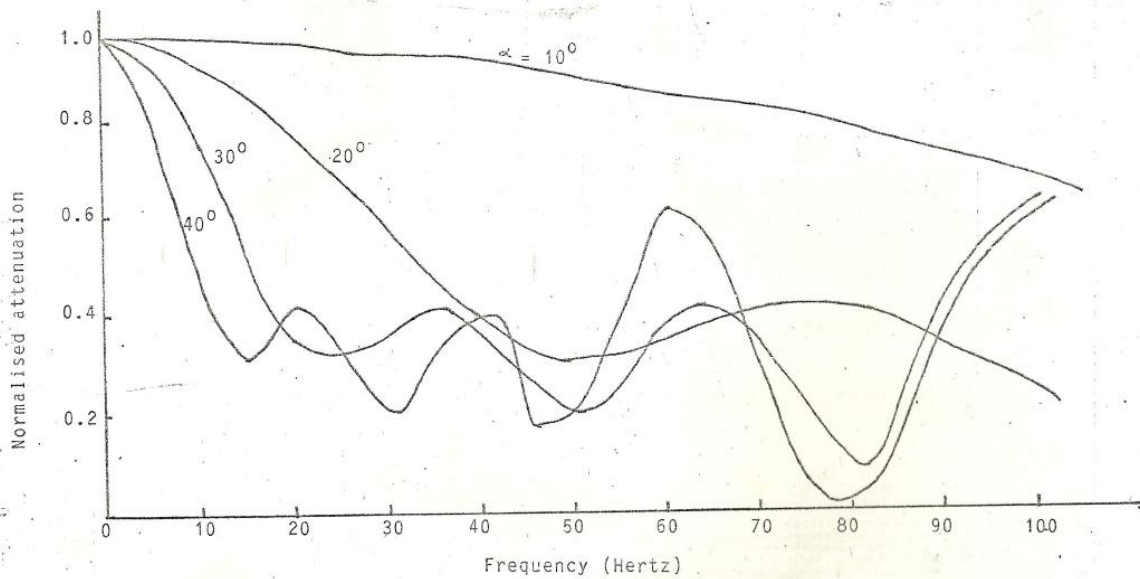


Figure 5: 6-Fold Straight Stack Response at Depth 3,000 m.

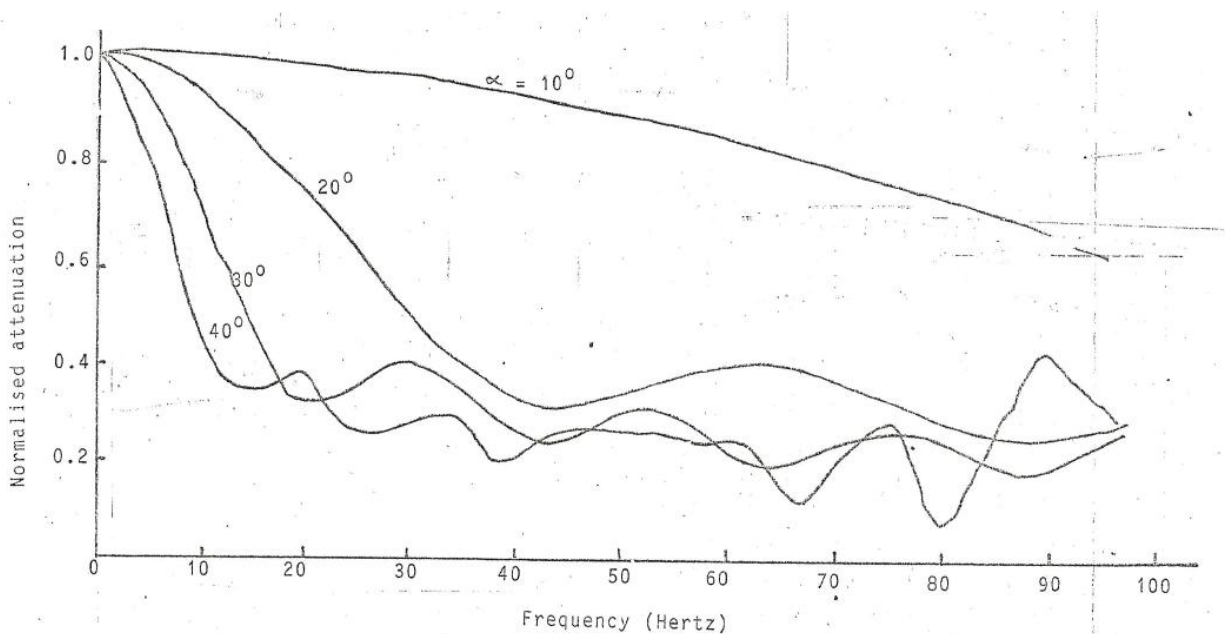


Figure 6: 12-Fold Straight Stack Response at Depth 3,000 m.

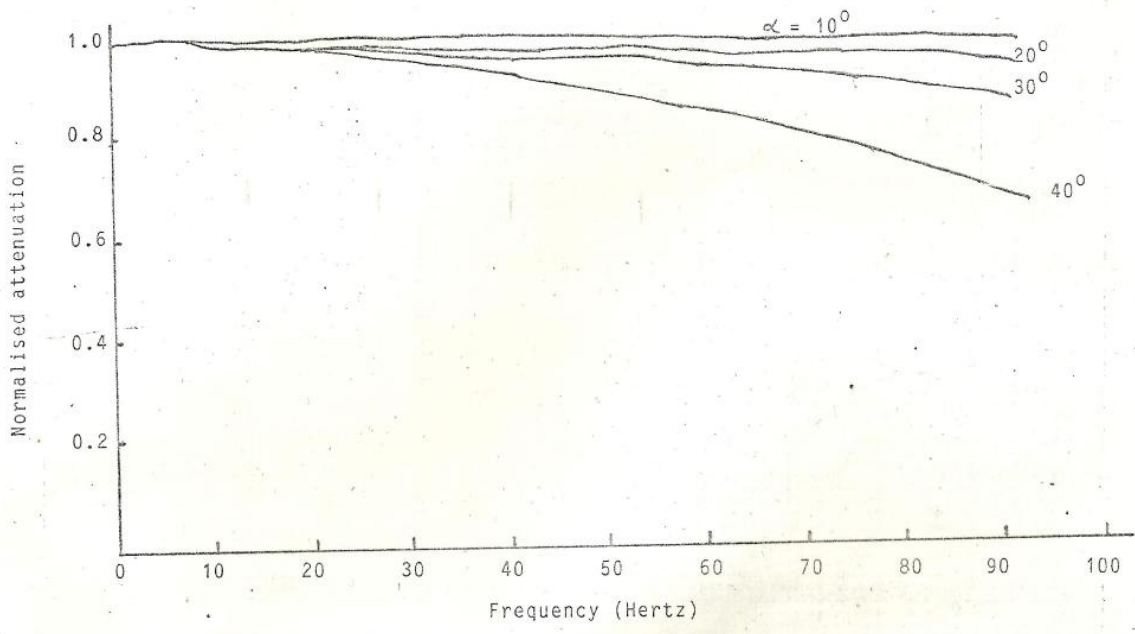


Figure 7: 3-Fold Straight Stack Response at Depth 4,800 m.

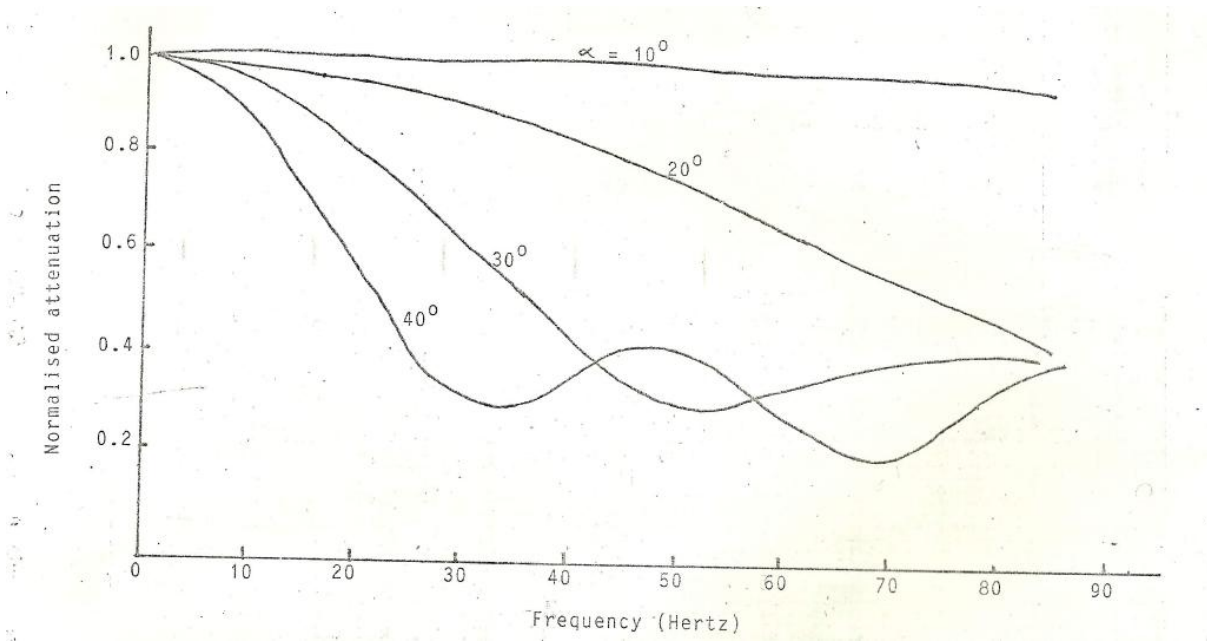


Figure 8: 6-Fold Straight Stack Response at Depth 4,800 m.

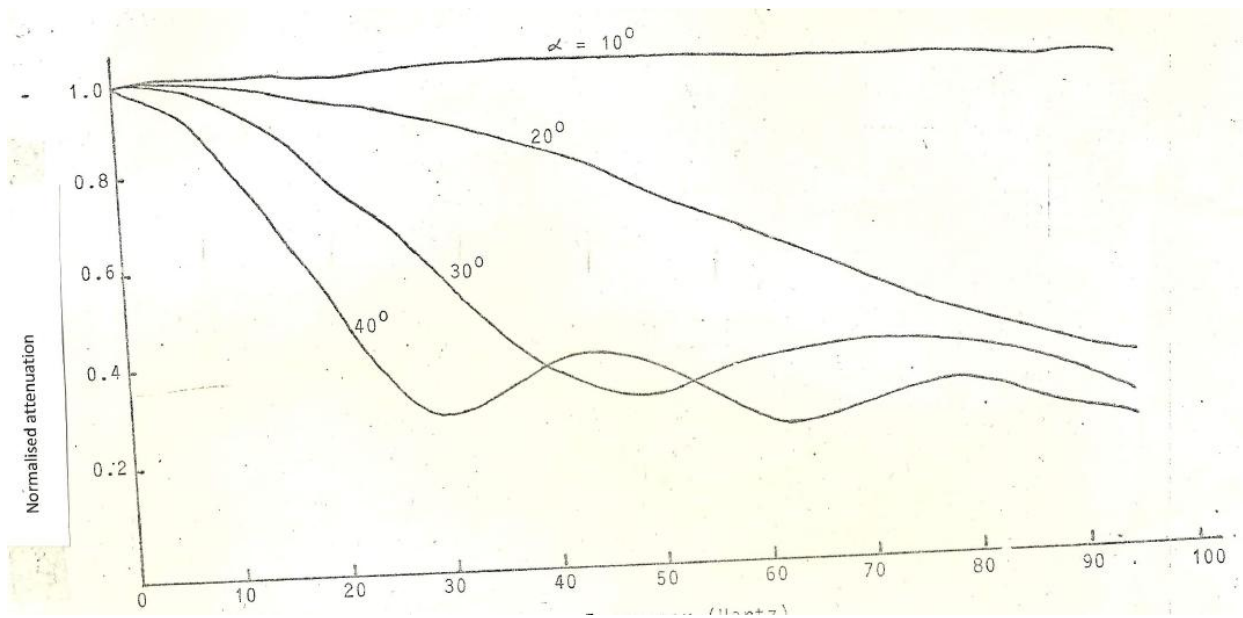


Figure 9: 12-Fold Straight Stack Response at Depth 4,800 m.

The graphs show that the attenuation of the wavelets increase with increasing dip and depth. The lower the multiplicity, the better is the stack response. In areas of low dips, 5° to 15° , the common depth point (CDP) can be applied successfully.

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