Diffracted noise attenuation in shallow water 3D marine surveys

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Summary

Attenuation of diffracted noise from shallow sea bed obstructions or geologic discontinuities can be achieved by locating the position of such obstructions with a semblance scan analysis and then extracting the noise from the traces at the calculated times for each obstruction.

Introduction

3D marine surveys occasionally suffer from scattering of source energy from sharp discontinuities at, or around, the sea bottom as the scattered energy gets recorded by the streamers. Nearby rigs, wellheads, shipwrecks, and, boulders at the sea bottom add to the problem. As the reflected energy from deep strata is weak and such scattered noise is much stronger than reflections, since it has traveled only in water, the position of these energy sources must be detected and the energy recorded on the seismic traces from such sources must be attenuated. Such strong energy interferes with many other pre-migration processes among which are prestack deconvolution and surface related multiple prediction, and therefore must be attenuated before reaching migration stage.

This problem had been recognized by Manin et al (1993) and a solution was suggested. Assuming that the coordinates of the noise source can be obtained they suggested flattening the data with static shifts corresponding to the travel times and suppressing the noise with existing multi-channel filters. Recently, Fookes et al, (2003) and Warner et al (2004) suggested picking arrival times of the noise, and then calculating the position of the noise source from the travel times and the coordinates of the source and receivers. Once the noise source is calculated the corresponding noise is attenuated as in the method proposed by Manin et al (1993). More recently, a method called "Diffraction imaging" is used by Khaidukov et al (2004) with 2D surveys for separately imaging weak point diffractors and thereby helping interpretation of faults in migrated seismic sections. Shtivelman et al (2004) uses multi-velocity imaging of subsurface inhomogeneities. The US Navy uses a method called "Low frequency active (LFA) sonar" to detect ultra quiet submarines using one streamer and one source. In the following paragraphs we will describe a method that will use 3D marine records (multi-streamers) and the best estimate of the water velocity to detect and suppress noise originating from shallow diffractors using the 3D marine shot records.

Our Method

As there can be hundreds of diffractors in cases where the water bottom contains outcrop and escarpments, it is not practical a) to pick the travel-times of every diffractor, b) to keep flattening each diffracted energy by external statics application programs and follow them with multi-channel processes. We aim to perform this automatically as will be described in the following paragraphs.

The energy of the diffracted noise travels from the source and hits the diffractor. The diffractor then scatters energy back, via Huygens Principle, and the energy arrives at the receivers at time

$$T = T_s + T_r \qquad \text{(Eq 1)}$$

where T_s is the time from source to diffractor

$$T_s = \frac{1}{V}\sqrt{(x_s - x_d)^2 + (y_s - y_d)^2 + z_d^2}$$

and T_r is the time from diffractor to receiver

$$T_r = \frac{1}{V}\sqrt{(x_r - x_d)^2 + (y_r - y_d)^2 + z_d^2} \quad .$$

Given a diffractor point D=(x_d,y_d,z_d) amplitudes of data at times T given in Eq 1 from all traces (i.,e. source S=(x_s , y_s,) and receiver R=(x_r, , y_r,) pairs) can be summed as in the migration process. Stack amplitudes, or stack power, could be used to estimate how strong this diffractor is. One can use other coherency measures as well for this purpose. Semblance is known to be the most efficient and practical coherency measure (Gulunay, 1991). Therefore, for every assumed diffractor position, D, we can obtain a semblance value, indicating how coherent energy from this diffractor is when some or ALL of the traces in the survey that get contaminated from this diffractor are considered. This idea is the essence of our method that we call "diffractor scanning", or simply, Dscan, similar to the well accepted term Vscan that is used for velocity scanning. In fact, Vscan was also used for migration velocity analysis by Gonzales et al (1984). Landa et al. (1987) used semblance scans to find diffractors buried in 3D half space in land seismic surveys. We use the best estimate of the water velocity in Eq. (1) and generally assume z_d=0 for shallow water cases. Note that given the finite record length (typically from 5 to 14 seconds) and for a given shot record there is a finite zone that one needs to scan to find the diffractor locations that are affecting that shot. That is, we only need to scan an area limited around our shot (source and receivers) controlled by water velocity, V, and recording time, T_L:

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$$x_1 \le x_d \le x_2 \text{ and } y_1 \le y_d \le y_2$$

$$x_1 = \min(x_r) - VT_L \ , \quad x_2 = \max(x_r) + VT_L$$
$$y_1 = \min(y_r) - VT_L, \quad y_2 = \max(y_r) + VT_L$$

Of course, we are not limited to one shot at a time, and can scan the whole data set for coherent diffractor locations if we care to do so. Our experience, however, has been that perhaps a shot by shot scan is the most useful as the diffractors may not appear consistent across the whole aerial extent of the survey, depending on how they are illuminated by the shot.

Field test with the Dscan method

We have tested this method on a sailline from a shallow water (about 60 ms) data set that was provided by Noble energy. Shots have 3 cables, each with 128 traces. The record length is 6 seconds and the sample interval is 2ms. A typical noisy shot is shown in Figure 1. Close inspection of the shot record suggests that there are ten or so diffractors but it is not easy to predict which event belongs to which diffractor.

The semblance scan of this shot using an area of 11km by 12 km gives the distribution shown in Figure 2. We used V=1538 m/s in the scans. The scan distance increment was 10m both in inline and crossline directions. Experience, however, shows that one does not have to be this precise. A coarser surface grid can be used but then the length of the time window used in semblance calculations has to be increased. Note that there is one semblance value for every point in the grid. An example of 10m by 10m grid semblance scan is shown in Figure 2. The hole in the middle of the semblance distribution shown in Figure 2 is due to the fact that first second of data was not included in the diffractor scan. Diffractor selection is now made using local maxima criteria with thresholding. The highest semblance value found in the search was 0.53. If the top 50 percent of the semblance values are used then 3 diffractors are detected, with the top 60 percent 6 diffractors and with the top 85 percent, 22 diffractors are detected.

Noise model building

For each of the diffractors selected from the semblance distribution travel times to the trace at hand can be calculated and the diffracted energy around that time picked to model the diffracted noise.

Figure 3 shows the result of this process for 22 diffractors picked from the semblance scan. By subtracting this model from the input (straight subtraction) we obtain a record that represents the signal only (Figure 4). Comparison of this result with the input record suggests that method is successful.

Conclusions

We have presented an automated method for attenuating diffracted energy from shallow water inhomegeneities that are harmful for 3D marine surveys. The method uses the double square root travel time equation and in essence is a migration/demigration type process except that it uses semblance instead of stacking amplitudes at constant depth (e.g. z_d=0) and applies signal processing methods to build the noise model instead of a demigration process.

Acknowledgments

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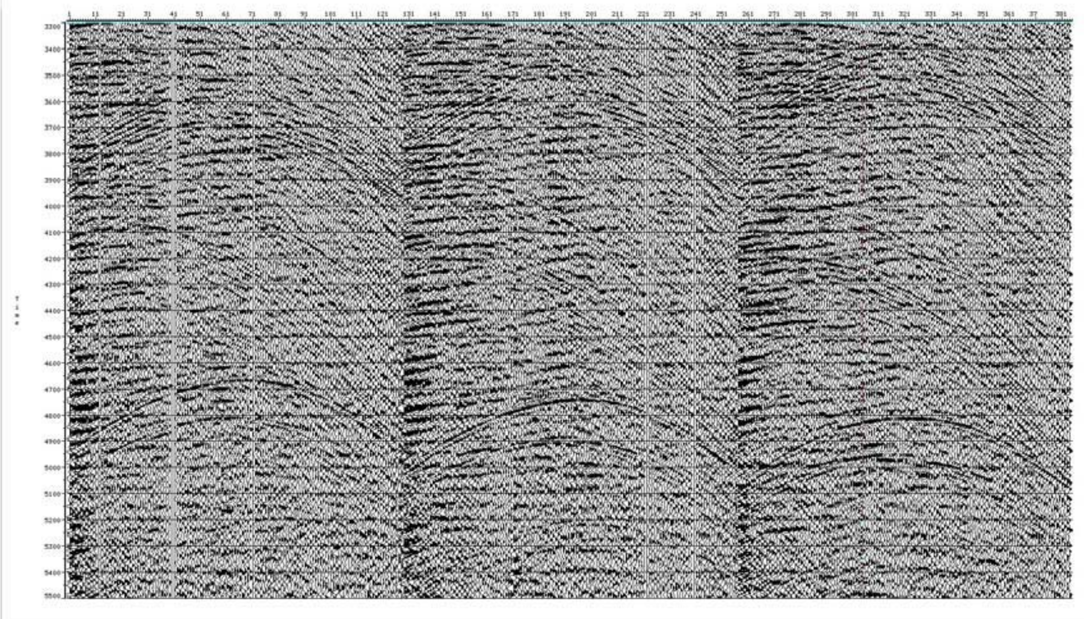

Figure 1: A shot with three cables contaminated with diffracted noise.

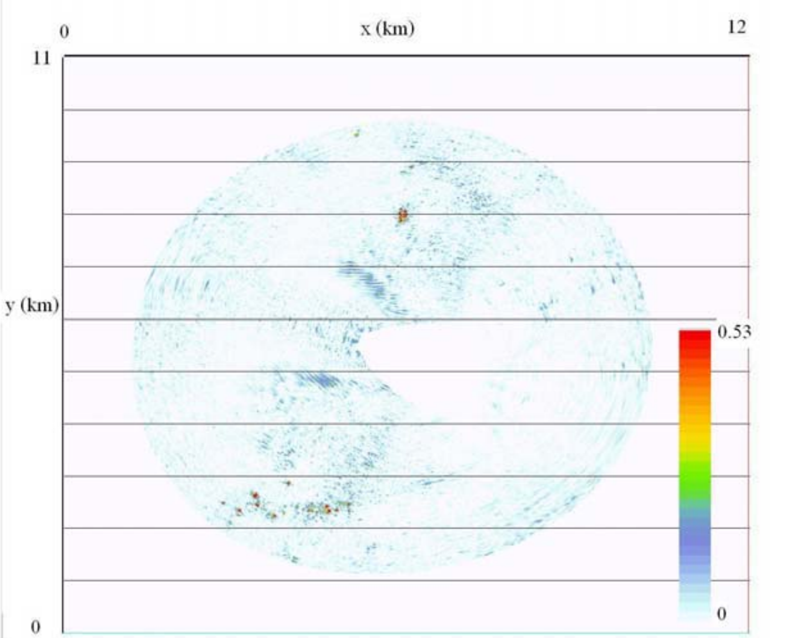

Figure 2: Diffractor semblance scan for the shot in Figure 1. Scan covers an area of 11km by 12 km.

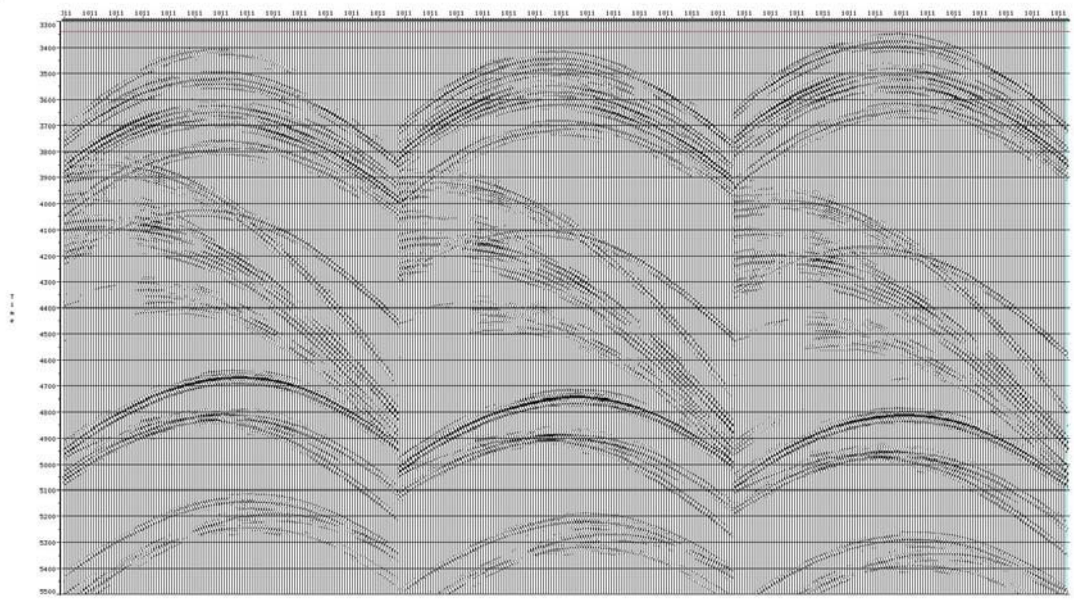

Figure 3: Diffraction model produced from top 22 diffractors

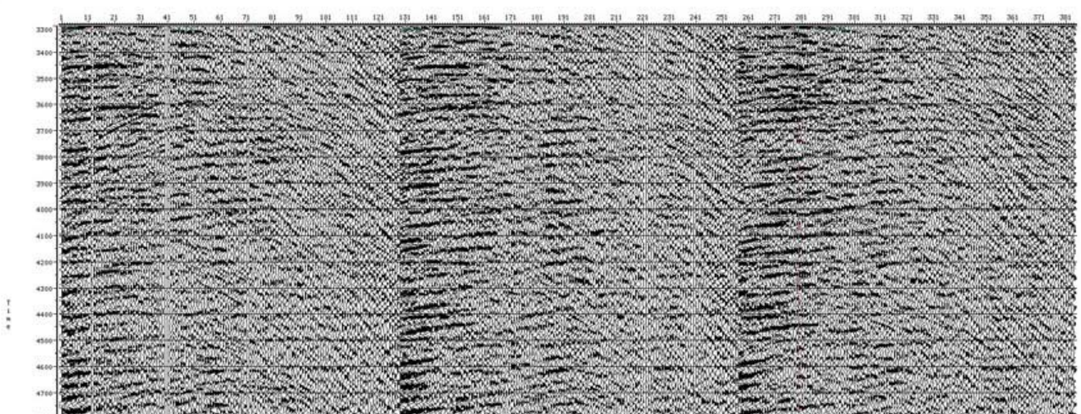

Figure 4: Shot after subtracting the model in Figure 3.

EDITED REFERENCES

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