United States Patent
Gulunay

7,739,051
June 15, 2010

Method for determination of diffractor locations at sea bottom for the purpose of attenuating such energy

Abstract

Coherency analysis, such as semblance scan or stacking amplitude, is used to locate diffractors. This is done utilizing traces of a recorded 3-D marine survey with one or more cables. Locations of each diffractor are determined by comparing the lateral coherency of the received amplitudes that each assumed diffractor position generates. Once the diffractors are located, noise energy originating from the diffractors is minimized.

Inventors: **Gulunay; Necati** (Missouri City, TX)
Assignee: **Compagnie Generale de Geophysique** (Massy Cedex, FR)
Family ID: **35600517**
Appl. No.: **10/890,793**
Filed: **July 14, 2004**

Prior Publication Data

Document Identifier	Publication Date
US 20060015259 A1	Jan 19, 2006

Current U.S. Class: **702/14**; 367/24
Current CPC Class: **G01V 1/28** (20130101); **G01V 2210/58** (20130101)
Current International Class: **G01V 1/00** (20060101); **G01V 1/38** (20060101)
Field of Search: **;702/14,5,11,17,18,1,2 ;367/37,38,43,15,24,21,47,73 ;166/252,250.01 ;324/323,326 ;703/2,5**

References Cited [Referenced By]

U.S. Patent Documents

3638176	January 1972	White
4797660	January 1989	Quaglino
4843597	June 1989	Gjessing et al.
4992991	February 1991	Young et al.
5008861	April 1991	Gallagher
5532976	July 1996	Schneider, Jr.
6049507	April 2000	Allen
6067273	May 2000	Sayers
6151556	November 2000	Allen
6292754	September 2001	Chambers et al.
6493636	December 2002	DeKok
6546339	April 2003	Bevc et al.
6687618	February 2004	Bevc et al.
6738715	May 2004	Shatilo et al.
6763305	July 2004	Bernitsas
6832160	December 2004	Vinje
6987596	January 2006	Wood
7085195	August 2006	Taner et al.
2005/0219949	October 2005	Taner et al.

Other References

Milkereit et al., Multiattribute Processing of Seismic Data: Application to Dip Displays, Dec. 1990, Canadian Journal of exploration Geophysics, vol. 26, Nos. 1&2, pp. 47-53. cited by examiner.
Keggin et al., Attenuation of Multiple Diffractions by Multi-Azimuth Streamer Acquisition, May 27-30, 2002, EAGE 64th Conference & Exhibition. cited by examiner.
Drag/out et al., Data Enhancement from a 500-Channel Streamer, Jan. 1984, IEEE Journal of Oceanic Engineering, vol. OE-9, No. 1, pp. 40-47. cited by examiner.
Tsai, C. James, An Analysis Leading to the Reduction of Scattered Noise on Deep Marine Seismic Records, Jan. 1984, Geophysics, vol. 49, No. 1, pp. 17-26. cited by examiner.
Bezdan, S., Experimental Seismic Surveys of the Trans-Hudson Orogen, 1998, A Thesis Submitted for the Ph.D. Degree, Department of Geological Sciences, University of Saskatchewan, Saskatoon. cited by examiner.
Ladd et al., Wide-Aperture Seismic Reflection Profiles Across the Barbados Ridge Complex, 1990, Proceedings of the Ocean Drilling Program, Scientific results, vol. 110, pp. 5-6. cited by examiner.
Taner et al., Velocity Spectra-Digital Computer Derivation and Applications of Velocity Functions, Dec. 1969, Geophysics, vol. 34, No. 6, pp. 859-881. cited by examiner.
Key et al., New Approach to Seismic-Reflection Event Detection and Velocity Determination, Aug. 1990, Geophysics, vol. 55, No. 8, pp. 1057-1069. cited by examiner.
Gulunay, N., High-Resolution CVS: Generalized Covariance Measure, 1991, 61st Ann. Int. Mtg.; Soc. of Expl., Geophysics, pp. 1264-1267. cited by examiner.
Gonzalez-Serrano et al., Migration Velocity Analysis in 3D, 1984 SEG Annual Meeting, Expanded Abstracts. cited by examiner.
Sicking, C., Diffraction Semblance for velocity and Structure Analysis, 1987 SEG Annual Meeting, Expanded Abstracts. cited by examiner.
Verweet et al., Relation Between Velocity Fields and Imaging in the Presence of Lateral velocity variations, 1985 SEG Annual Meeting, Expanded Abstracts. cited by examiner.
Landa et al., A Method for Detection of Diffracted Waves on Common-Offset Sections, 1987, Geophysical Prospecting 35, pp. 359-373. cited by examiner.
Landa et al., Seismic Monitoring of Diffraction Images for detection of Local Heterogeneities, Mar-Apr. 1998, Geophysics, vol. 63, No. 3, pp. 1093-1100. cited by examiner.
Blonk et al., Inverse Scattering of Surface Waves: A New Look At Surface Consistency, Jan. 1994, Geophysics, vol. 59, No. 6, pp. 963-972. cited by examiner.
Brittan et al., An Elastodynamic Inverse Scattering Method for Removing Scattered Surface Waves from Field Data, Nov.-Dec. 1995, Geophysics, vol. 60, No. 6, pp. 1897-1905. cited by examiner.
Fookes et al., Practical Interference Noise Elimination in Modern Marine Data Processing, 2003 SEG Annual Meeting, Expanded Abstracts, pp. 1905-1908. cited by examiner.

Primary Examiner: Nghiem; Michael P
Assistant Examiner: Le; Toan M
Attorney, Agent or Firm: Strasburger & Price, LLP

Claims

The invention claimed is:

1. A computer implemented method of determination of diffractor location utilizing traces of a recorded 3-D marine survey with one or more cables, comprising the steps of: A. Selecting coordinate boundary; B. Calculating lateral coherency values, wherein the coherency value is calculated using amplitudes of traces at calculated travel times; and C. Determining diffractor location in the coordinate boundary area using the coherency values; wherein the determination of the diffractors is determined by requiring that a local maxima point on a coherency plot be the largest amplitude in a space (x, y) window; wherein there is included the step of taking all points which satisfy the following equation as possible diffractor locations, the equation being: a.sub.i,j.gtoreq.a.sub.i-n,j-v for -n.ltoreq.n.ltoreq.n and -v.ltoreq.v.ltoreq.v where u and v are non-zero integers and a.sub.m,n are amplitudes.

Description

FIELD OF THE INVENTION

The present invention relates to geophysical prospecting using seismic signals, and in particular an automatic method for determining the locations of the shallow inhomogeneities or obstacles (to be called diffractors or scatterers) that scatter back energy radiated from source to the recorded sections in 3-D marine surveys.

BACKGROUND OF THE INVENTION

In the field of geophysical prospecting, seismic signals are used to do 3-D seismic surveys of a predetermined area. However, problems arise in the collection of data due to the backscattering of energy from the shallow inhomogeneities or obstacles.

Prior Art at Compagnie Generale de Geophysique:

Compagnie Generale de Geophysique utilizes a process called Deterministic Diffractor Noise Reduction (DDNR) to remove the contribution of diffractor energy from the survey. DDNR involves identifying and picking travel times for each diffractor located at sea bottom. Once travel times are known for a diffractor, then its location can be calculated by assuming a speed of propagation, like 1500 m/s, for the medium. Data can then be flattened using travel times calculated for the diffractor and the flat component of energy (diffraction) can be attenuated using FK filter or Radon transform filter, as it is known in the art.

Prior Art in the Industry:

Fookes et al. ("Practical interference noise elimination in modern marine data processing." Expanded Abstracts, 2003 SEG Annual Meeting) follow a method similar to Compagnie Generale de Geophysique DDNR method mentioned above: pick travel times and find the diffractor location that minimizes the error between calculated travel times and measured travel times. Upon determination of diffractor location, the data is flattened and the energy is attenuated.

A use of coherency measurement is using semblance in stacking velocity analysis of seismic data and is done by Taner and Koehler (1969, "Velocity spectra--digital computer derivation and applications of velocity functions," Geophysics, 34, 859-881). The use of other coherency measures than semblance for lateral coherency of events is also possible: energy normalized cross correlation sum, stacking power, or stacking amplitude are other possibilities. Key and Smithson (1990, "New approach to seismic-reflection event detection and velocity determination" GEOPHYSICS, Soc. of Expl. Geophys., 55, 1057-1069.) derived their coherency measures from the eigenvalues of the problem at hand. Gulunay (1991, "High resolution CVS: Generalized covariance measure", 61st Ann. Internat. Mtg: Soc. of Expl. Geophys., 1264-1267) studied the relationship of such coherency measures including the ones derived from semblance. Gonzalez-Serrano and Chun ("Migration velocity analysis in 3-D," Expanded Abstracts, 1984 SEG Annual Meeting), Sicking ("Diffraction semblance for velocity and structure analysis," Expanded Abstracts, 1987 SEG Annual Meeting), and VerWest et al. ("Relation between velocity fields and imaging in the presence of lateral velocity variations," Expanded Abstracts, 1985 SEG Annual Meeting) use semblance analysis for prestack migration velocity determination. Landa et al. ("A method for detection of diffracted waves on common offset sections," Geophysical Prospecting, 35, 359-373, 1987) use semblance which is find buried edges to x-z plane that cause diffraction under a 2-D seismic line (shooting and receiving along a direction, shots and receivers at the surface, z=0) using common offset data. Landa and Keydar ("Seismic monitoring of diffraction images for detection of local heterogeneities," Geophysics, 63, 3, 1093-1100, May 1998) use semblance analysis to detect local heterogeneities (diffractors) buried under a 2-D section (x-z plane) using a source receiver configuration similar to the ones used in 2-D seismic recordings (shooting and receiving along a z direction, shots and receivers at the surface, z=0). The paper discusses a "D-section" which is similar in concept to semblance scanning; however, D-section is done for diffractor buried in a vertical plane of a complex earth. U.S. Pat. Nos. 6,687,618 and 6,546,339 also address the use of semblance scan in geophysical processing using seismic signals.

Two papers by Blonk et al (1994, "Inverse scattering of surface waves: A new look at surface consistency", Geophysics, 59, 6, 963-972 and 1995, "An elastodynamic inverse scattering method for removing scattered surface waves from field data", Geophysics, 60, 6, 1897-1903.) address the issue of finding and removing such diffractors for land data but their method is based on "linearized elastodynamic inverse scattering theory" and involves consideration of temporal frequency, solution of linear system with tools like conjugate gradient algorithm and is completely different from the time domain amplitude coherency approach of the arrival energy used in this invention.

It is an object of this invention to remove the energy from the survey that is contributed by the diffractor.

It is a further object of the present invention to eliminate the task or necessity of picking of arrival or travel-times or going into complex theoretical calculations as in Blonk et al (1994,1995) papers for determination of diffractor locations.

SUMMARY OF THE INVENTION

Diffraction is a wave phenomenon where a source radiates energy to a medium and an obstacle in the medium scatters that energy back to an array of receivers placed in the same medium. Seismic energy radiated by air guns in a 3-D marine survey, in water or at shallow part of the earth, scatters back (diffracts) from diffractors located at the water bottom, contaminating the seismic sections. Materials left at the sea bottom, such as wellheads, shipwrecks, even outcropping geology, may act like diffractors.

The present invention eliminates the task of picking arrival times by judging the likelihood of a tested location to be a diffractor point by calculating coherency of arrivals from that point. The present invention preferably utilizes semblance scan as a coherency analysis tool to minimize the energy contributed by the survey by diffractors. Any of the aforementioned measures could be used for coherency calculation; however, semblance derived measures are the most advantageous. First, they are the most economical to use. For this reason, the present invention uses semblance as the coherency measure. Second, semblance is sensitive to the coherency of the event but not to its actual strength. For example, stack amplitude for a five-sample event with amplitudes $(1,1,1,2,1)$ is $6/5=1.2$ and its semblance is 0.9. Stack amplitude for $(10,10,10,20,10)$ is $60/5=12$ but its semblance is still the same and is 0.9. An event could be weak but it could be coherent while an event could be strong but it may not be coherent.

In the present invention, locations of each diffractor are determined by comparing the lateral coherency of the received amplitudes that each assumed diffractor position generates. That is, these are the locations that are in agreement with the travel paths observed on the recorded traces. The amplitudes of the diffraction (data generated from received traces at the travel times (or around the travel times) calculated by using the source position and the location of the diffractor as a function of a source-receiver pairs, and is sensed by a receiver (or receivers) coherently, indicating semblance. Among the ways to judge that a tested location is a diffractor point or not is to compute semblance scanning; however, if we compute a disastrous result. As a method to overcome this problem, the amplitudes picked to be put into the semblance calculation can come from the traces (source-receiver pairs) of one or many sources and one or many array of receivers (called cables or streamers). This allows points with large semblance to be picked, thereby eliminating the need for picking travel times for each diffractor. Once a diffractor location is known, then data can be flattened using sum of the travel times from source to diffractor and from diffractor to receiver and then applying one of the methods of prior art, such as FK filtering, Radon filtering, etc. to remove such energy contributed by this diffractor.

DESCRIPTIONS OF THE DRAWINGS

For further understanding of the nature and objects of the present invention, reference should be had to the following figures in which like parts are given like reference numerals and wherein:

FIG. 1 shows boat sail-line patterns on a typical 3-D marine survey;

FIG. 2 shows source-diffractor-receiver travel path;

FIG. 3 shows arrival times of diffraction that are received from a diffractor by a boat carrying five cables;

FIG. 4 shows xmax range for a given cable;

FIG. 5 shows a semblance plot generated from 20 shots each with 8 cables, each cable with 120 traces;

FIG. 6 shows local maxima picker; and

FIG. 7 shows flattening a diffractor.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In seismic prospecting for oil and gas, a boat 10 pulls a set of receivers 15 $((x.sub.r,y.sub.r)$ positions) placed on structures referred as "streamers" or "cables". The boat 10 has airguns (not shown but well known in the art) placed near it and these guns fire at certain intervals $((x.sub.s,y.sub.s)$ positions) creating a seismic disturbance that travels into layers of earth and is reflected from each layer and received by these receivers. Reflections generally come from vertical slices of earth, which are called "subsurface lines" or "common midpoint lines," formed by the geometry of the recording. There are as many subsurface lines as there are cables. The boat 10 generally travels on a straight line to cover an area of interest and then turns back and places itself on the next survey line with to produce more subsurface lines as shown in FIG. 1. Surface lines may overlap. It is imperative that while surveys on recorded represents reflections from strata, but there are many noise types recorded. Among them is the scattered energy from inhomogeneities at sea bottom or material that are at the sea bottom as wells, wellheads, sunken ships, etc. The scattered energy from the inhomogeneities are what the present invention seeks to eliminate.

A 3-D marine survey is generally recorded with patterns depicted in FIG. 1. A boat 10 pulling a number of streamers 15 starts from a point, like point 1, and travels to point 2. Direction from Point 1 to Point 2 could be any azimuth, i.e. not necessarily a south to north line. The boat turns at point 2 and travels until point 3 and makes another turn at point 3. It then travels to point 4 and makes another turn. It travels to point 5 and then makes another turn, and so on. Therefore, a fully 3-D illustration makes the survey area consists of many lines indicated by points (1,2,3,4), (5,6,7,8), and so forth, are formed.

In the present invention, the initial step in locating the diffractors is to determine the minimum x value, maximum x value, minimum y value, and maximum y value of the receiver coordinates for the whole survey, as shown in FIG. 1. This is done by looking at the trace headers on the data. (A source receiver pair is called a trace.) These values are called: X.sub.min, X.sub.max, Y.sub.min, Y.sub.max, respectively. These values are then extended by an amount that a seismic wave can travel in the water velocity in the recording time. These two extensions and maximum extension are generally equal the largest distance along the x axis, X.sub.min~X.sub.max=VT.X.sub.min~X.sub.max=VT.X.sub.min~VT.sub.min+VT.sub.max ....sub.min~X.sub.max... ...where V=water velocity and T is the maximum extension (generally half of the record length of a trace given in seconds) and so forth.

X and Y grid sizes, dx and dy respectively, are chosen to scan this area. Grid size (scan increment) used is typically 25 m both in x and y. Because the grid increments lower than 25 m and scan increments as high as 100 m can be used. However, the finer the scan increment, the more accurate the location determination for the diffractors. Of course, the run time is the more expensive. Sampling coarser than 100 m is not expected to yield accurate travel times for flattening the diffractors for the purpose of noise attenuation.

Then, for each point $(x.sub.d, y.sub.d)$ on the grid defined by: x.sub.d=X.sub.min+(i-1)*dx $(i=1,2, ..., i.sub.max)$ x.sub.d=X.sub.min+(j-1)*dy $(j=1,2, ..., j.sub.max)$ where i.sub.max=1+(X.sub.max-X.sub.min)/dx j.sub.max=1+(Y.sub.max-Y.sub.min)/dy a coherency value is calculated using amplitudes, as picked from traces. For each point $(x.sub.d, y.sub.d)$ that corresponds to (using (i,j) indices) a scattered energy (i.e., diffraction travel times will be calculated from source to point $(x.sub.d, y.sub.d)$ and from point $(x.sub.d, y.sub.d)$ to receiver) for each source receiver pair $(x.sub.s, y.sub.s), (x.sub.r, y.sub.r)$ and many amplitudes corresponding to these (i,j) grid point is a diffractor point or not is to compute the diffraction travel times the diffractor point is located at a better value to use for the normalization.

There are many coherency measures available in the prior art. As discussed in the background and summary of the invention, it is possible to use stack amplitudes, stack power, energy normalized cross-correlation sum, or semblance. This invention uses the conventional semblance defined by:

$$
\text{Semblance} = \frac{\sum \left(\sum \text{Amp} \right)^2}{N \sum \sum \text{Amp}^2} \qquad \#EQU00001\#\#
$$

Semblance Calculation from a Single Time Sample per Trace

If selectivity is desired, one can use functions of semblance as discussed by Gulunay, (1991). Some of the useful functions are:

$$
\dots \#EQU00002\#\#
$$

This invention preferably uses semblance (Eq. 1 or its smoothed version to be given in Eq. 4). Once such a semblance distribution is obtained, $S(i,j)$ (i=1,2, ..., i.sub.max, j=1,2, ..., j.sub.max) max local maxima in this function can be found by requiring a point to be larger than all of its points in its neighborhood, (e.g. a 100 m by 100 m part of the grid). Among all such points, the ones with significant values can be selected as valid diffractors.

FIG. 2 depicts a source (point S) pulling some streamers (5 cables) with typically hundreds (even thousands) of receivers (point R) placed on them. As source radiates energy travels to diffractor point D and is scattered back. Scattered energy radiates back omwnds of the receivers (points like R) on the streamers 15.

Arrival time of diffracted energy is the sum of two terms: source term, T.sub.1, and receiver term T.sub.sub.2, as shown in FIG. 2. As source $(x.sub.s, y.sub.s, z.sub.s)$ and receiver $(x.sub.r, y.sub.r, z.sub.r)$ coordinates are known, the time of arrival time of diffracted energy, for this source-diffractor $(x.sub.d, y.sub.d, z.sub.d)$ can be calculated using a medium velocity, V, like 1500 m/s. The equation for this calculation is given in Eq. 2.

Travel Time Equation for Source-Diffractor-Receiver Travel Path

Here Z.sub.d represents the relative (with respect to the source and receivers) depth of the diffractor which is assumed to be zero in general but one can scan for a range of depths as well, if desired.

Indeed, if stacking amplitude

$$
\dots \#EQU00004\#\#
$$

Stack Amplitude as an Attribute

rather than semblance values (defined in Eq. 1) are calculated, this invention will produce pre-stack migration, done for a small range of depths, and with velocity, V (medium velocity). Therefore, using such stack amplitudes for picking the location of diffractors in half space $(x.sub.d,y.sub.d,z.sub.d)$ is also a new approach.

To illustrate the method, note that arrival times from hyperbolic looking events 25 as depicted in FIG. 3 (for a small set of (five) cables). Each vertical line 20 in FIG. 3 depicts a trace (source-receiver pair) recorded by receiver on a cable during a particular 3-D shot. The wavelets on the traces depict diffracted energy. The amplitude value, as $(a=1,2, ..., N$ where N is the number of traces that diffraction is recorded at the time calculated by Eq. 2 for each source-receiver pair that can record energy from this diffraction will be recorded by using the available traces on the cables. These recorded amplitudes will be picked and put into the semblance calculation as is shown by Eq. 1.

When the travel time falls between the two time samples of the digitally recorded seismic trace then the value of sample is interpolated from the nearby samples with known techniques of the prior art.

To indicate the reliability (trustworthiness) of semblance values, as it is known in prior art, it is possible to use more than one time sample (centered at the arrival time) for a trace to improve the reliability of the semblance calculation. In this case semblance, now becomes a function of a single one time sample per trace, and becomes a multi-samples function; (A.sub.m,n) where n=arrival time and m=samples

$$
\text{Semblance} = \frac{\sum_m \left(\sum_n A_{m,n} \right)^2}{M \sum_m \sum_n A_{m,n}^2} \qquad \#EQU00005\#\#
$$
where rows, m=1, 2, ..., M, represent time and columns, n=1, 2, ..., N, represent space (traces). Semblance calculations, as it is known in prior art, are made using Eq. 4.

$$
\text{.times. .times. .times. .times. .times. .times.} \#EQU00006\#\#
$$

Semblance Calculation from M Samples per Trace (Samples Centered at the Arrival Time)

The value of M can be arbitrary. However, practice shows that large values of M are not helpful. Lower values of M are preferable to increase both peak semblance values and resolution in time, which is also referred to as "resolution" . A value of M equal to 3 or 4 is recommended. However, it is important to notice that increasing resolution to increase resolution in the coherency of the diffraction distribution. A value of M about the size of the main peak of the diffracted arrival wavelet is best.

It is mentioned above that N in Eq. 1 is the number of traces that a diffractor has contaminated. There could be many such traces, coming from many sources and many streamers. There is not an increased benefit in using all these of contributions which are part of one semblance measure, as the "fold" in the gathers increases. Therefore they can come together and cables. For example, noise content differences would be such obstacle. It was found that using only traces from one shot and one cable at a time in time tends to work best, As there are as many cables $(i=1,2, ..., N.sub.c)$ and many (d) shots $(i=1,2, ..., N.sub.s)$, for each pair of shot and cable.

..function..times..times..function..times. $\#EQU00007\#\#$

Semblance Accumulation from Many Cables and Shots

One needs to keep track of the number of values summed for each position (i,j), known elsewhere as "fold," so that the results could be divided by its maximum to achieve physically meaningful semblance values (between 0 and 1). This is known as "normalization". It is also possible to use the fold value at each location to do the normalization (i.e., normalization that the fold value at each location for a 3-D survey and hence, can be a possible) and use that to normalize the contributions of each streamer. Otherwise, it can be normalized with the maximum value of the fold (i.e. the peak fold found in the scan area) but this is harder value to use for the normalization.

For determination of the diffractor azimuth and individual scan values,

1) For cables that are not far from the shot, as in current 3-D marine recordings, one cable alone cannot tell the azimuth of the diffractor. That is, a diffractor doesn't tell us two points that are symmetrical with respect to the line (formed by that cable) that contains one source and one receiver (perpendicular to this line cable). The diffractor points lie on the cable from multiple cables experiences the improved value (due to the surface diffractor value). In any case, the minimum of the x coordinate and the angle is called x.sub.d which one can use to determine azimuth considering diffractors with x coordinate that are at the same azimuth. For determination of diffractor azimuths requires the use of two cables (for 2 cables). Similarly, if u and d are minimum and maximum found in one or more directions; and from vT' and d=d'=VT' is sufficient. Here V represents medium velocity and T represents recording time or before.

FIG. 5 shows the results of semblance scan obtained from 20 shots $(N.sub.s=20)$ each pulling 8 cables $(N.sub.c=8)$. Horizontal axis 30 is the x-coordinate and vertical axis 35 is the y-coordinate. In s-coordinate the semblance towards the survey grid. The x coordinate 30 of the survey grid, T, is indicated by axis 30 with 120 traces. Each coordinate has been viewed here is preferably 10 m in both x and y directions. There are eight local maxima on it, seen as 5 m and as high as 100 m can be used. The finer the sampling towards the semblance was found to work best. Sampling coarser than 100 m is not preferred for obtaining accurate travel times for the flattening of diffractors for the purpose of noise attenuation. The color code 40 is shown at the lower right corner of FIG. 5. Semblance values vary between zero and one. Peak semblance value for this run was 0.239. Semblance values above 0.100 are plotted in the Figure.

FIG. 5 provides a visual display of the diffractor locations. It covers an area of roughly 40 km sq.2. Actual locations are machine picked by requiring that a local maxima point needs to be the biggest amplitude in space (x, y) window, typically and preferably 100 m by 100 m. FIG. 6. This can be explicitly, a user given smooth and dimension domain, in the semblance plot (above the threshold, defined by the above); window size is the size of the window (in m by m), with number (1, 3, 5, ... , if window size is $2m+1$ by $2m+1$), defined in FIG. 6, one should use points in the x and y direction to determine the local maxima. Max value and local maxima need to be compared with the coherency values of its surrounding neighbors.

.gtoreq..times..times..times..times..times..times. $\#EQU00008\#\#$

Local Maxima Diffractor Definition

where u and v are integers except u=v=v=0. All i and j increments, except the edges, i.e. all the points satisfying m+1.ltoreq.i.ltoreq.i.max-m and n+1.ltoreq.j.ltoreq.j.max-n, are each checked and (i,j) points satisfying Eq. 8 are taken to be a diffractor location. Order in which one varies i and j depends on how the scan values are stored, in the computer by rows or (i.sub.r or sub.c, n.1). In order to determine if it is the largest amplitude in $2m+1$ by $2m+1$ neighborhood.

FIG. 6 illustrates local maxima search routine. 50 for a 3-by-3 window for simplicity. For a center point 55 to become a local maxima, it must be greater than its eight neighbors 57-65. For a 5-by-5 window the middle point must be greater than its 24 neighbors. For a $(2m+1)$-by-$(2m+1)$ window the middle point must be greater than its $(2m+1)(2m+1)-1$ neighbors.

Once a set of such diffractor locations are found, one can use methods known in prior art to flatten and apply a filter and attenuate the diffraction energy for each location. Flattening is a process (depicted in FIG. 7) where diffracted event's travel times 60 are subtracted from the trace. This is known in prior art as "static shift". During this static shift, care must be taken not to lose reflection (reflections shift away slightly while flattening and static shift towards selected diffractor locations using these coherency data. Filter at the diffractor location.

There are numerous tools in geophysical industry to remove the diffraction data. Known among them are FK filter, regular and high-resolution radon filter, eigenvalue filter, etc. Any one of these could be used to remove the coherent energy. Flattening data and applying FK filter and flattening energy resolution is discussed below. Two or more diffractors in the vicinity of one another, or even in the embodiment herein described, accordingly, but for the energy scattered energy is important for each diffractor should be ensured that one is dealing with the diffractions of the same diffractor at a time.

Because many varying and different embodiments may be made within the scope of the invention concept taught herein which may involve many modifications in the embodiments herein described in accordance with the descriptive requirements of the law, it is to be understood the details herein are to be interpreted as illustrative and not as a limiting sense.

* * * * *