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(54) Title: METHOD FOR DETERMINING A HIGH FREQUENCY ENVELOPE ATTRIBUTE FROM SEISMIC DATA

(57) Abstract: A method of for computing a high frequency envelope attribute from seismic data involves selecting a 1D trace of the seismic data and computing an envelope for the 1D trace. A high frequency envelope attribute is computed by adding the envelope to any quantity derived from the 1D trace.

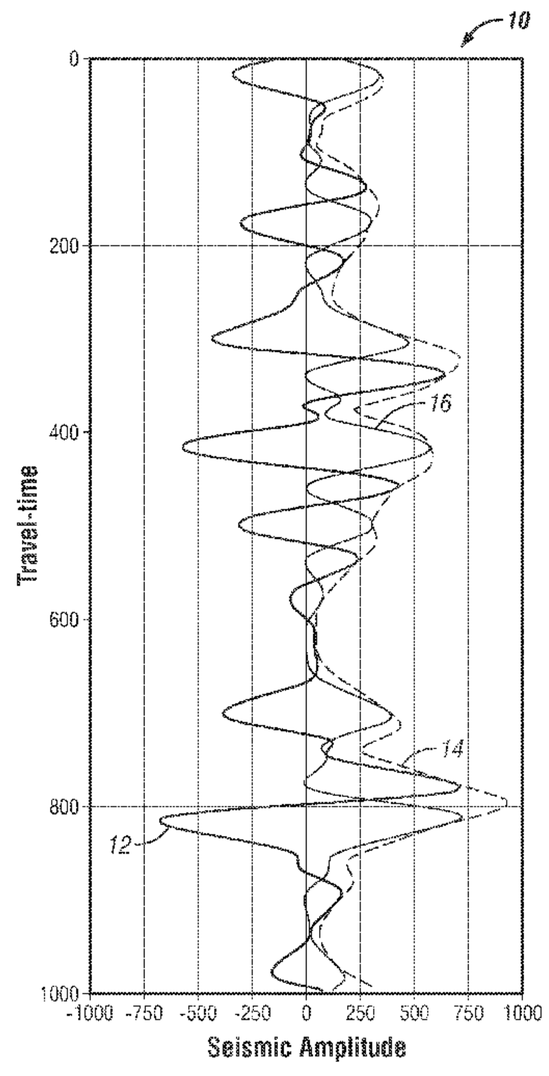


FIG. 3

WO 2021/092201 A1

METHOD FOR DETERMINING A HIGH FREQUENCY ENVELOPE ATTRIBUTE FROM SEISMIC DATA

FIELD OF THE INVENTION

[0001] The present invention relates to interpretation of seismic data and, more specifically, to a method for determining a high frequency envelope attribute from seismic data.

BACKGROUND OF THE INVENTION

[0002] Geophysical data are used for hydrocarbon exploration and other geotechnical studies. Field-acquired geophysical data includes, for example, seismic and other remote-sensing data, and well logging data. Interpretation of the data assists in understanding the structural and stratigraphic features and determining the probability of presence of hydrocarbons and other fluids in an area of interest.

[0003] Multi-dimensional geophysical data is often enhanced using attributes, such as seismic amplitude, phase, frequency, continuity, and the like. Taner et al ("Complex seismic trace analysis" Geophysics 44:6:1041-1063; 1979) relates to the unique separation of envelope amplitude and phase information and calculation of instantaneous frequency. The quantities can then be displayed in color coding.

[0004] US5,226,019 (Bahorich) relates to stratigraphic analysis of geophysical data. Seismic data are transformed into one or more instantaneous attributes descriptive of the wave-like nature of seismic signals. Upper and lower boundaries are identified for a stratum or region of interest. A statistically representative descriptor of one or more instantaneous attributes over the stratum defined by the boundaries is obtained to determine lateral and vertical variations within the stratum. The values of the instantaneous attributes are combined between the upper and lower boundaries for forming a single descriptor over the stratum of interest. Then, the single descriptor is used to produce a display of the single descriptor for identifying and characterizing changes in the formation.

[0005] In general, conventional techniques have insufficient or poor resolution for identifying subtle stratigraphic features in seismic data.

[0006] There is a need for an improved method for seismic interpretation that overcomes the disadvantages of conventional techniques for seismic interpretation of subtle stratigraphic features.

SUMMARY OF THE INVENTION

[0007] According to one aspect of the present invention, there is provided a method for computing a high frequency envelope attribute from seismic data, comprising the steps of: obtaining seismic data and selecting at least one 1D trace of the seismic data; computing an envelope for the at least one 1D trace of the seismic data; and computing the high frequency envelope attribute by adding the envelope to any quantity derived from the at least one 1D trace of the seismic data.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The method of the present invention will be better understood by referring to the following detailed description of preferred embodiments and the drawings referenced therein, in which:

[0009] Fig. 1 is reproduced from a Prior Art reference showing a portion of an actual seismic trace;

[00010] Figs. 2A – 2B are reproduced from a Prior Art reference showing real and quadrature traces of a portion of an actual seismic trace, an envelope, a phase, and frequency;

[00011] Fig. 3 illustrates one embodiment of the method of the present invention with a negative amplitude focus; and

[00012] Fig. 4 illustrates another embodiment of the method of the present invention with a positive amplitude focus.

DETAILED DESCRIPTION OF THE INVENTION

[00013] The present invention provides a method for improved interpretation of seismic data by preserving phase content and the full frequency content of a waveform of the seismic data. In this way, the method of the present invention allows subtle stratigraphic features in seismic data to be identified.

[00014] As discussed above, Taner et al ("Complex seismic trace analysis" Geophysics 44:6:1041-1063; 1979) relates to the unique separation of envelope amplitude and phase information and calculation of instantaneous frequency. Advantages of the method of the present invention are more evident by first considering Taner et al's envelope.

[00015] Fig. 1 is reproduced from Taner et al. Fig. 1 is an isometric diagram of a portion of an actual seismic trace 1. As discussed in Taner et al, the "complex trace $F(t)$ can be

thought of as the trace in complex space of a vector which is continually changing its length and rotating, thus tracing out an irregular helix." A real trace 2 and a quadrature trace 3 for the real trace 2 are given by the projection of a trace of the rotating vector on the real and imaginary planes 4,5, respectively.

[00016] Figs. 2A – 2B are also reproduced from Taner et al. Fig. 2A shows a real trace 2 for a portion of an actual seismic trace 1, while Fig. 2B illustrates a quadrature trace 3 for the real trace 2. As noted by Taner et al, both the real trace 2 and the quadrature trace 3 are identical except that they are phase-shifted by 90 degrees.

[00017] The dashed curve in Figs. 2A and 2B represents an envelope 6 computed for real trace 2 and quadrature trace 3, respectively. As can be seen from Figs. 2A and 2B, the envelope 6 produced by Taner et al's method is independent of the phase of the real trace 2 and effectively forces symmetry about a center of a layer. While there are recognized benefits of the forced symmetry, a disadvantage of relying on the envelope 6 alone is an over-simplification of complex asymmetries.

[00018] In accordance with the method of the present invention, there is no assumption of symmetry relative to a center of a layer. Accordingly, it is possible to visualize more complex asymmetries, allowing for a more complex representation of layering.

[00019] A high frequency envelope attribute is computed from seismic data. The seismic data is preferably at least 1D. At least one 1D trace of the seismic data is selected from the seismic data. Seismic data can be provided in a time-domain, depth or frequency-domain.

[00020] An envelope is computed for the at least one 1D trace of the seismic data, for example, using the method described in Taner et al.

[00021] A high frequency envelope attribute is computed by adding the envelope to any quantity derived from the at least 1D trace of the seismic data. In one embodiment of the present invention, the high frequency envelope attribute is computed by adding the envelope to the seismic data. In another embodiment of the present invention, the high frequency envelope attribute is computed by adding the envelope to a negative of the seismic data. The high frequency envelope attribute is used to visualize or interpret subsurface properties, especially for subtle and/or complex subsurface properties. The high frequency envelope attribute may be used as an input to analytical or computational processes, including, without limitation, processes described in US10,249,080B2 (Griffith) and US20190080507A1 (Griffith).

[00022] Fig. 3 illustrates one embodiment of the method of the present invention 10. An input 1D seismic trace 12 has seismic amplitudes ranging from to – 690 to + 720 for a travel time ranging from 0 to 1000. The input seismic trace 12 in Fig. 3 has about 20 major peaks on either side of 0 amplitude. An envelope 14, represented by the dotted line, was computed from the input 1D seismic trace 12, using the method of Taner et al. The envelope 14 has about 9 positive peaks, the largest having an amplitude of about 930. A high frequency envelope attribute 16 was computed by adding the envelope 14 to a negative of the 1D trace of the seismic data 12. The high frequency envelope attribute 16 has about 13 positive peaks, the largest having an amplitude of about 720, consistent with the input seismic trace 12.

[00023] In accordance with the present invention, the resolution is approximately twice as sensitive for vertical localization of subsurface features. For example, in Fig. 3, for a travel-time in the range of 300 – 600, the envelope 14 has 3 major peaks, while the high frequency envelope attribute 16 has 5 major peaks in the same range. Another example of vertical localization is to measure the thickness of the 1D time-series above or below an amplitude threshold. Resolution or vertical localization is improved when the range of travel-times is smaller. For example, examine the values just below the travel-time of 400 where the input 1D seismic trace 12 has amplitude less than -400 in the travel-time range 403 – 429, the envelope 14 has an amplitude above 400 in the range 391 – 464, and the high frequency envelope attribute 16 has an amplitude above 400 in the travel-time range 400 – 433. By this measurement, the high frequency envelope attribute 16 matches very closely the range for the input 1D seismic trace 12 and is approximately half of the range for the envelope 14, or double the resolution.

[00024] Referring now to Fig. 4, in another embodiment of the present invention, the input seismic trace 12 and the envelope 14 are the same as in Fig. 3. In this embodiment, a high frequency envelope attribute 16 was computed by adding the envelope 14 to the 1D trace of the seismic data 12.

[00025] As evidenced by the embodiments illustrated in Figs. 3 and 4, the high frequency envelope attribute preserves a phase content and a frequency content of a waveform of the seismic data, as compared to relying on the envelope alone.

[00026] The present invention is particularly advantageous for petroleum exploration. The seismic trace can reveal information about the changes in rock properties, including, without limitation, lithology, porosity, pore fluid, facies changes, and the like. Those skilled in the art

examine, among other things, the reflectivity at boundaries of rock layers, especially on boundaries that correspond to a reservoir. The skilled artisan will, therefore, focus on either positive or negative peaks in the seismic trace. This focus will inform the artisan's decision on whether to compute the high frequency envelope attribute by adding the envelope to the seismic data or by adding the envelope to the negative of the seismic data.

[00027] While preferred embodiments of the present invention have been described, it should be understood that various changes, adaptations and modifications can be made therein within the scope of the invention(s) as claimed below.

CLAIMS

1. A method for computing a high frequency envelope attribute from seismic data, comprising the steps of:
    - obtaining seismic data and selecting at least one 1D trace of the seismic data;
    - computing an envelope for the at least one 1D trace of the seismic data; and
    - computing the high frequency envelope attribute by adding the envelope to any quantity derived from the at least one 1D trace of the seismic data.
2. The method of claim 1, wherein the seismic data is at least 1D.
3. The method of claim 1, wherein the high frequency envelope attribute is used to visualize or interpret subsurface properties.
4. The method of claim 1, wherein the high frequency envelope attribute is used as an input to analytical or computational processes.
5. The method of claim 1, wherein the envelope for each 1D trace is computed from any quantity derived from the seismic data.
6. The method of claim 1, wherein the high frequency envelope attribute is computed by adding the envelope to the seismic data.
7. The method of claim 1, wherein the high frequency envelope attribute is computed by adding the envelope to the negative of the seismic data.
8. The method of claim 1, wherein the high frequency envelope attribute preserves a phase content and a frequency content of a waveform of the seismic data.

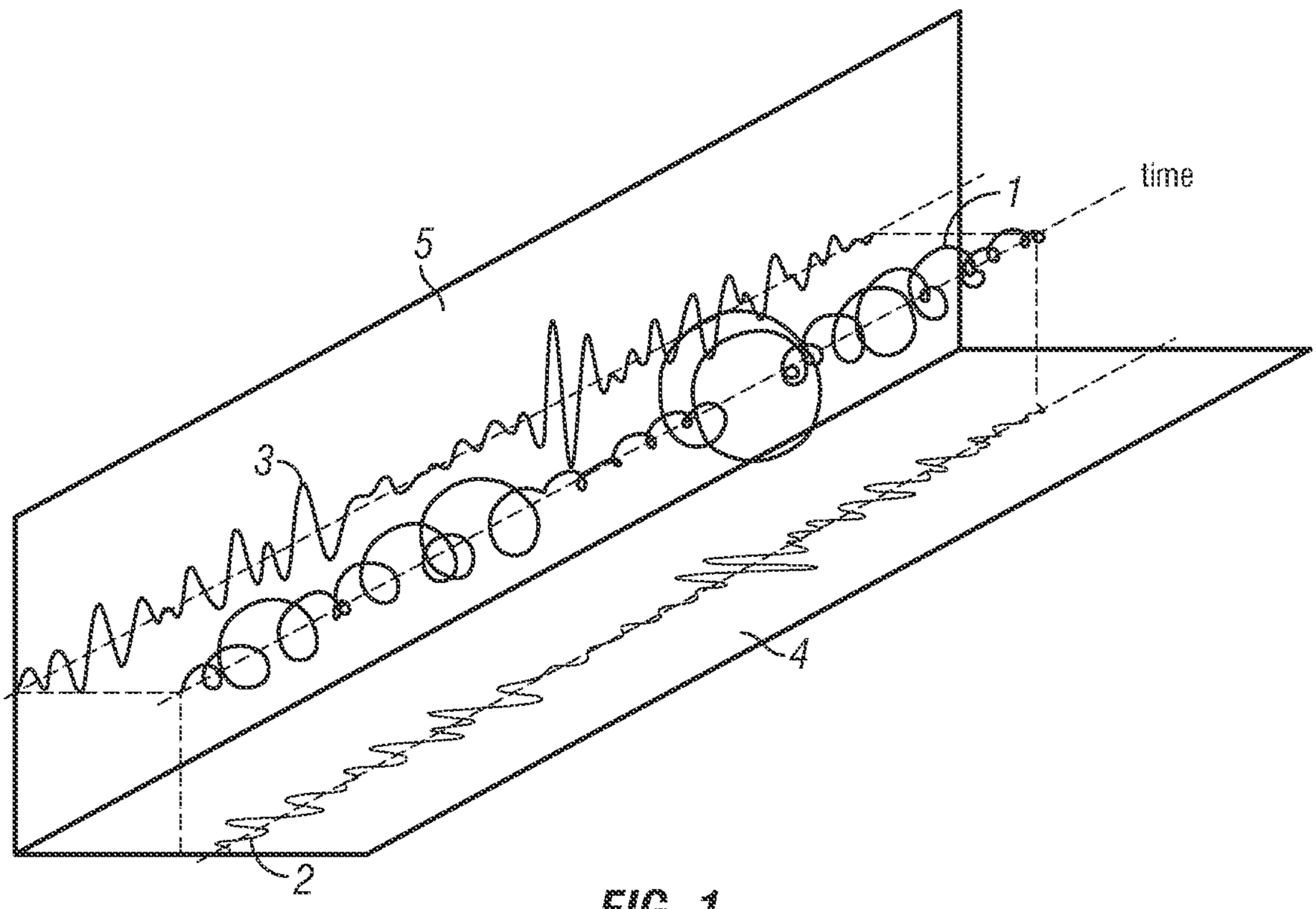


FIG. 1
(Prior Art)

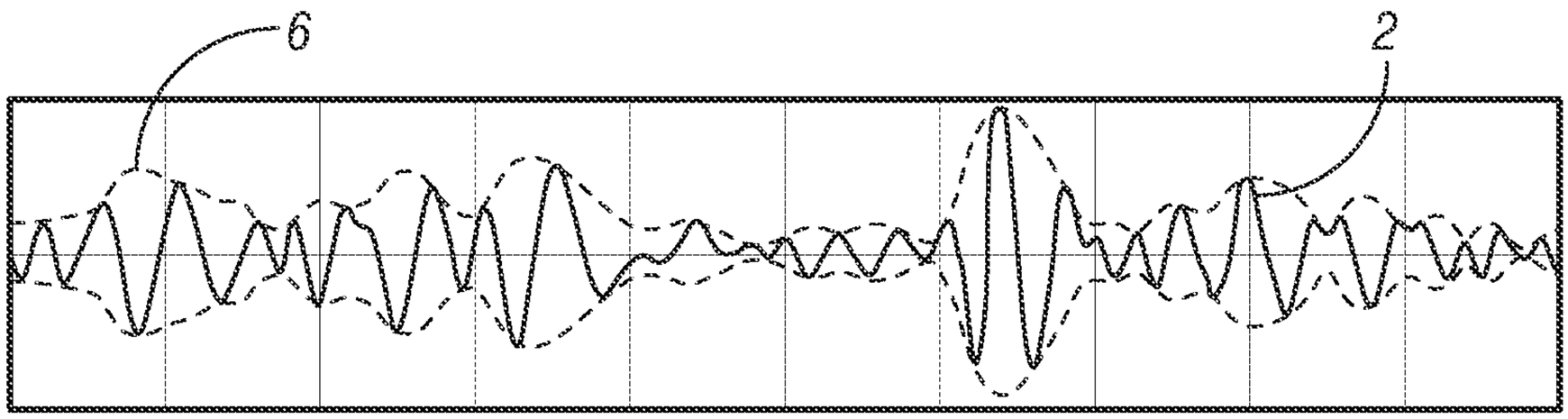


FIG. 2A

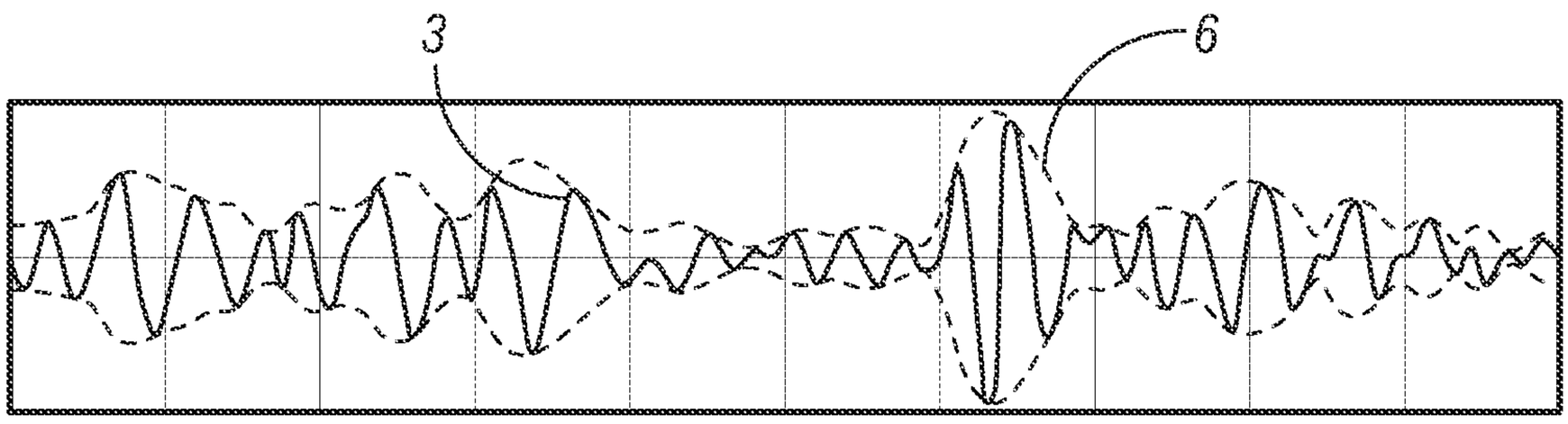


FIG. 2B

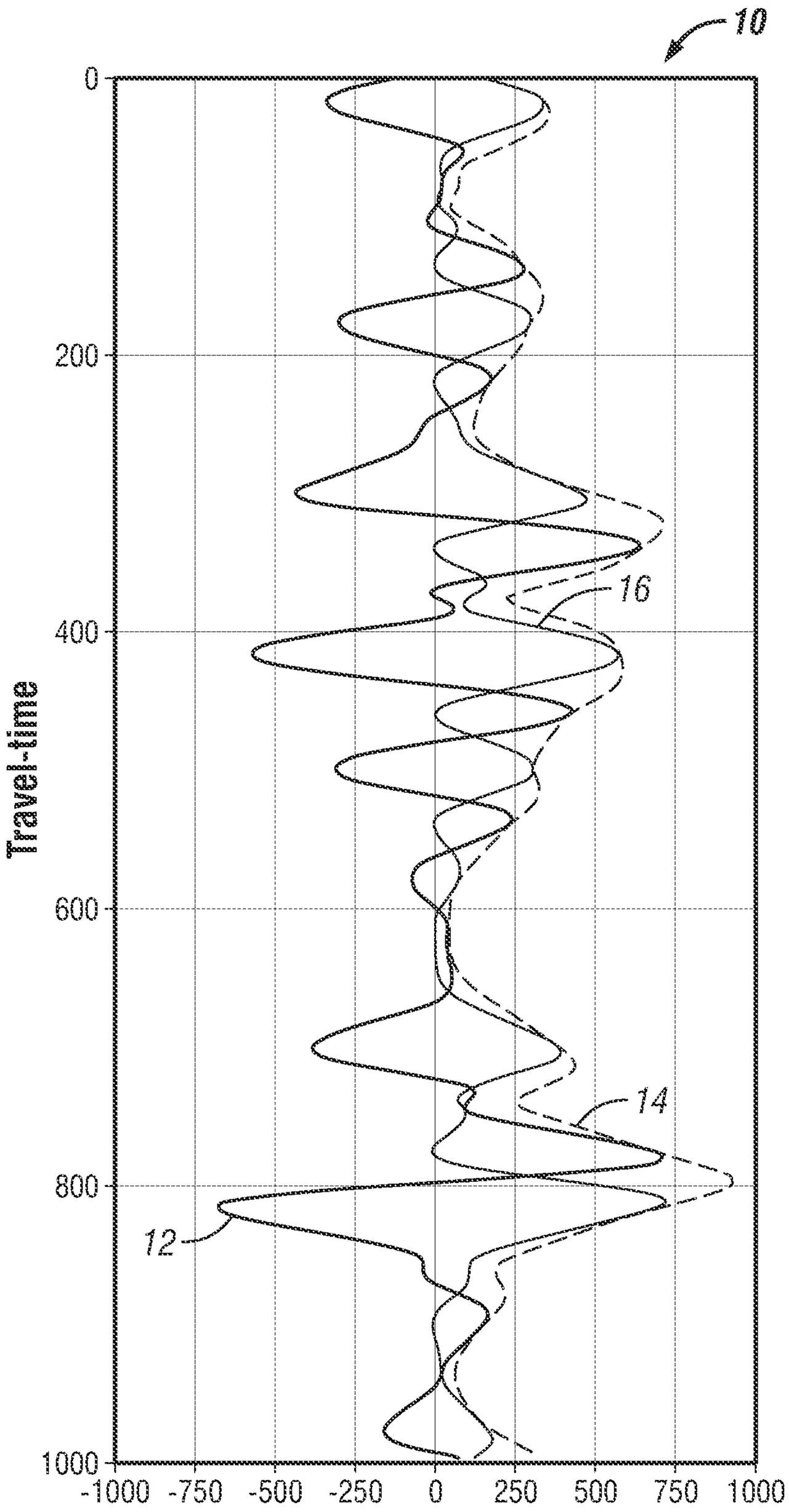

10
16
14
12
0
200
400
600
800
1000
Travel-time
-1000
-750
-500
-250
0
250
500
750
1000
Seismic Amplitude

FIG. 3

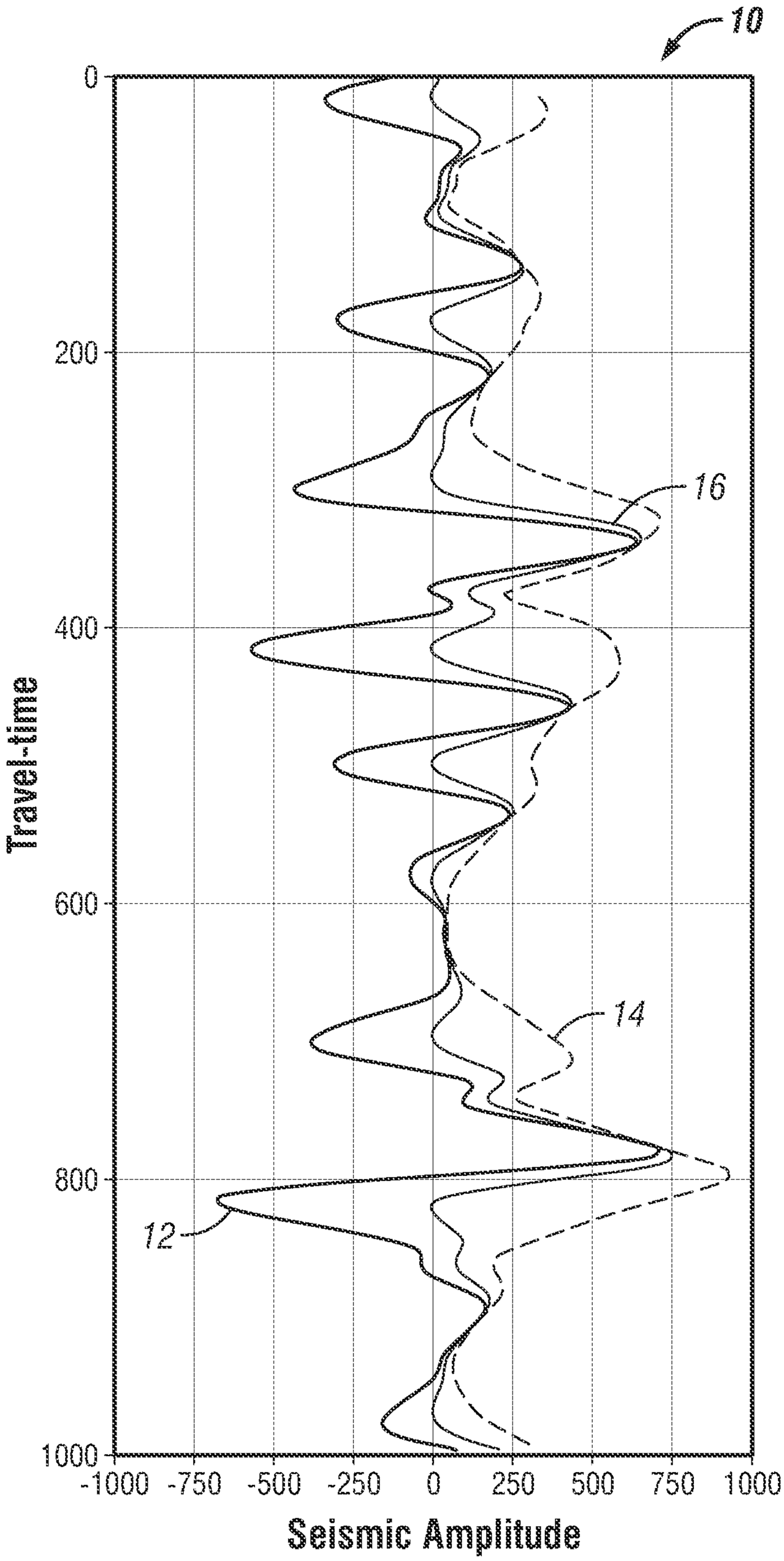

10
0
200
400
600
800
1000
Travel-time
16
14
12
-1000
-750
-500
-250
0
250
500
750
1000
Seismic Amplitude

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2020/059146

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01V1/30 G01V1/32
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KARSLI H ET AL: "APPLICATION OF COMPLEX-TRACE ANALYSIS TO SEISMIC DATA FOR RANDOM-NOISE SUPPRESSION AND TEMPORAL RESOLUTION IMPROVEMENT", GEOPHYSICS, SOCIETY OF EXPLORATION GEOPHYSICISTS, US, vol. 71, no. 3, 1 May 2006 (2006-05-01), pages V79-V86, XP001243689, ISSN: 0016-8033, DOI: 10.1190/1.2196875 Section CTT METHOD figures 5-6 Section Real data examples Section CONCLUSIONS ----- -/--	1-5,8

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
12 February 2021	23/02/2021
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Lameloise, C

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2020/059146

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JIAN-GUO SONG ET AL: "Decomposition of seismic signal based on Hilbert-Huang transform", BUSINESS MANAGEMENT AND ELECTRONIC INFORMATION (BMEI), 2011 INTERNATIONAL CONFERENCE ON, IEEE, 13 May 2011 (2011-05-13), pages 813-816, XP031948448, DOI: 10.1109/ICBMEI.2011.5917060 ISBN: 978-1-61284-108-3 II. A. Empirical Mode Decomposition -----	1,2,4-8
X	CN 109 212 603 A (UNIV BEIJING POSTS & TELECOMM; CTBT BEIJING NAT DATA CENTRE) 15 January 2019 (2019-01-15) claim 1 -----	1,2,4-8
A	US 5 226 019 A (BAHORICH MICHAEL S [US]) 6 July 1993 (1993-07-06) cited in the application the whole document -----	1-8

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2020/059146

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 109212603 A	15-01-2019	NONE	
US 5226019 A	06-07-1993	NONE	