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[Continued on nextpage]

(54) Title: SYSTEM AND METHOD FOR INVESTIGATING SUB-SURFACE FEATURES OF A ROCK FORMATION

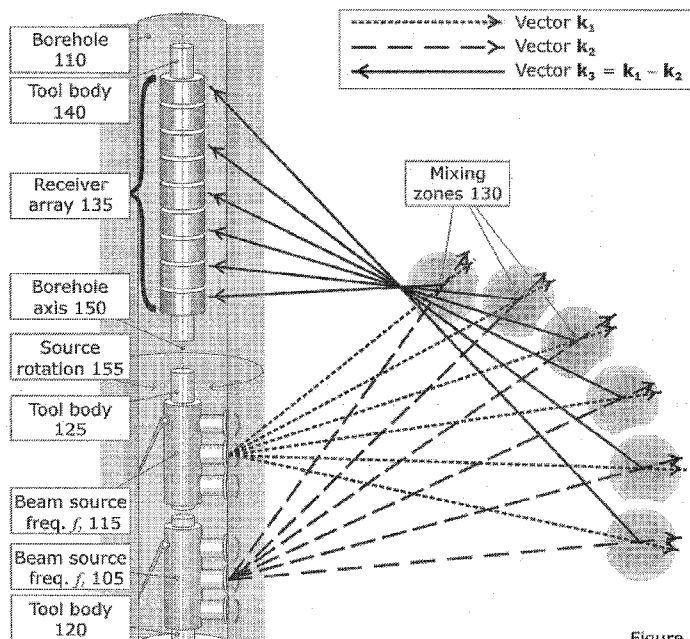


Figure 1

(57) Abstract: A method and system for investigating rock formations outside a borehole are provided. The method includes generating a first acoustic wave at a first frequency by a first acoustic source (105); and generating a second acoustic wave at a second frequency by a second acoustic source (115). The first and the second acoustic waves intersect in an intersection volume (130) outside the borehole. The method further includes receiving a third acoustic wave at a third frequency, the third shear acoustic wave returning to the borehole due to a non-linear mixing process in a non-linear mixing zone within the intersection volume at a receiver (135) arranged in the borehole. The third frequency is equal to a difference between the first frequency and the second frequency.

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LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,  
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# INTERNATIONAL SEARCH REPORT

International application No <b>PCT/US2011/059967</b>
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A. CLASSIFICATION OF SUBJECT MATTER  
 INV. G01V1/46  
 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.
<b>X</b>	US 2010/265794 A1 (JOHNSON PAUL A [US] ET AL VU CUNG [US] ET AL) 21 October 2010 (2010-10-21) abstract; claims 1-10,14-19,34-39; figures 1,4-6 paragraphs [0020] - [0025], [0028], [0030] - [0032], [0036], [0039] - [0041], [0044], [0045] -----	1-22

Further documents are listed in the continuation of Box C.       See patent family annex.

\* Special categories of cited documents :

<p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>	<p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&amp;" document member of the same patent family</p>
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Date of the actual completion of the international search  14 December 2012	Date of mailing of the international search report  21/03/2013
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  Fernandes, Paulo

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/US2011/059967
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Patent document cited in search report		Publication date		Patent family member(s)	Publication date
US 2010265794	AI	21-10-2010	AR	076325 AI	01-06 -2011
			AR	076326 AI	01-06 -2011
			AU	2010236139 AI	27- 10-2011
			AU	2010236226 AI	10- 11-2011
			CA	2758938 AI	21-10 -2010
			CA	2758959 AI	21- 10-2010
			CN	102395903 A	28- 03-2012
			CN	102395904 A	28-03 -2012
			EA	201171254 AI	30-03 -2012
			EA	201171255 AI	30-05 -2012
			EP	2419762 AI	22- 02-2012
			EP	2419763 AI	22-02 -2012
			JP	2012524271 A	11- 10-2012
			JP	2012524272 A	11-10 -2012
			US	2010265794 AI	21-10 -2010
			US	2010265795 AI	21-10 -2010
			Wo	2010121200 AI	21-10 -2010
			Wo	2010121202 AI	21-10 -2010

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US2011/059967

## Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2.  Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
  
3.  Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
  
2.  As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
  
3.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
  
4.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-22

### Remark on Protest

The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

No protest accompanied the payment of additional search fees.

## FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

## 1. claims: 1-22

System/method for investigating rock formations comprising 2 acoustic sources emitting intersecting signals at different frequencies and a receiver to detect the resultant signal at a frequency equal to the difference of frequencies of the sources.

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## 2. claims: 23-64

System/method for investigating rock formations comprising 2 acoustic sources emitting intersecting signals at different frequencies and a receiver to detect the resultant signal at a frequency equal to the difference of frequencies of the sources wherein the acoustic signals comprise a plurality of pulses.

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## 3. claims: 65-107

System/method for investigating rock formations comprising 2 acoustic sources emitting intersecting signals at different frequencies and a receiver to detect the resultant signal at a frequency equal to the difference of frequencies of the sources wherein a storage device is provided to store specific measurement parameters.

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## 4. claims: 108-128, 134-153, 186, 187, 215, 216

System/method for investigating rock formations comprising 2 acoustic sources emitting intersecting signals at different frequencies and a receiver to detect the resultant signal at a frequency equal to the difference of frequencies of the sources wherein the acoustic signals comprise a plurality of pulses and a second processor is provided to generate a 3D image of non-linear properties of a rock formation.

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## 5. claims: 129-133, 154-158, 183-185, 212-214

System/method for investigating rock formations comprising 2 acoustic sources emitting intersecting signals at different frequencies and a receiver to detect the resultant signal at a frequency equal to the difference of frequencies of the sources wherein a 3D image of non-linear properties of a rock formation is generated and a wave velocity model is iteratively updated.

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## 6. claims: 159-182, 188-211

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

System/method for investi gati ng rock formati ons compri si ng 2  
acousti c sources emitti ng intersecti ng signal s at di fferent  
frequenci es and a recei ver to detect the resul tant signal at  
a frequency equal to the difference of frequenci es of the  
sources wherei n the acousti c signal s are conical .

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7. claim: 217

Plural ity of interconnected subsystems for investi gati ng  
non-l inear properti es of a rock formati on.

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