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(54) **METHOD AND SYSTEM FOR DETERMINING SOURCE SIGNATURES AFTER SOURCE GHOST REMOVAL**

2010/0008184 A1* 1/2010 Hegna G01V 1/36
367/21
2010/0211319 A1 8/2010 van Manen et al.
2012/0033526 A1* 2/2012 Hegna G01V 1/364
367/21

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FOREIGN PATENT DOCUMENTS

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EP 0400769 A2 12/1990
EP 2249182 A1 11/2010
EP 2626727 A2 8/2013

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OTHER PUBLICATIONS

(21) Appl. No.: **13/367,787**

Parkes, "A marine seismic acquisition system that provides full 'ghost-free' solution" SEG San Antonio 2011 Annual Meeting, Sep. 23, 2011.*

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Ziolkowski, "The signature of an air gun array" Computation from near-field measurements including interactions Geophysics vol. 47, No. 10 (Oct. 1982).*

(65) **Prior Publication Data**

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O. V. Kishkovich, Eurasian Search Report, mailing date: Jul. 2, 2013. Ziolkowski A., "The signature of an air gun array: Computation from near-field measurements including interactions", Geophysics, vol. 47, No. 10 (Oct. 1982), p. 1413-1421.

(51) **Int. Cl.**
G01V 1/38 (2006.01)

Monk D.J., "Wavefield separation of twin streamer data", First Break, vol. 8, No. 3, Mar. 1990, p. 96-104.

(52) **U.S. Cl.**
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(58) **Field of Classification Search**
CPC G01V 1/3808; G01V 1/3861; G01V 2210/56
See application file for complete search history.

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(56) **References Cited**

U.S. PATENT DOCUMENTS

2005/0013194 A1 1/2005 Vaage et al.
2005/0259513 A1* 11/2005 Parkes G01V 1/006
367/23
2006/0227660 A1* 10/2006 Grion G01V 1/3808
367/24
2008/0192371 A1* 8/2008 Hubbs G02B 5/12
359/883
2008/0192571 A1 8/2008 Vaage et al.
2008/0253227 A1 10/2008 Söllner

(57) **ABSTRACT**

Seismic data are acquired using a seismic source comprising a plurality of seismic sub-sources disposed in a body of water at a plurality of depths and activated with different time delays. Far-field signatures are determined for the plurality of seismic sub-sources at each of the plurality of depths. A composite ghost-free far-field signature of the seismic source is determined from the far-field signatures for the plurality of seismic sub-sources at each of the plurality of depths and different time delays. A source response is removed from the seismic data using the far-field signatures of the seismic source.

10 Claims, 4 Drawing Sheets

