

~~Horizontal Streamer Broadband Marine Seismic Acquisition Configuration and Processing~~
Method For Acquiring And De-ghosting Marine Seismic Data

PRIORITY INFORMATION

[1] The present application is related to, and claims priority from, U.S. Provisional Patent Application No. 61/695,915, entitled "Horizontal Streamer Broadband Marine Seismic Acquisition Configuration and Processing", filed on August 31, 2012, the disclosure of which is incorporated here by reference, as well as U.S. Provisional Patent Application No. 61/722,204, entitled "Seismic Target Illumination", filed on November 4, 2012, the disclosure of which is incorporated here by reference..

BACKGROUND

1. Technical Field

[2] Examples of the subject matter disclosed herein generally relate to methods and systems for seismic exploration and, in particular methods and systems for seismic data acquisition and seismic data processing directed to de-ghosting.

2. Description of the Background

[3] To map subsurface geology during exploration for oil & gas or other minerals and fluids a form of remote sensing is employed to construct three dimensional images of the subsurface. The method relevant to this specification is known as seismic surveying where an energy source transmits pressure pulses into the earth which maybe reflected by geological interfaces in it and subsequently recorded at the surface by arrays of detectors. Such surveys are conducted on land using geophone detectors which vibrate and displace a magnet within a coil to induce an electric potential, or hydrophones in a marine environment which detect pressure changes due to the reflected wave-field and also induce an electric signal which may be recorded. In the marine environment the source's energy is transmitted and received from the subsurface via the water layer, the surface of which at the air-water interface, acts like a mirror by reflecting energy. As

SUMMARY

[22] According to an embodiment aspect of the present invention, a method for acquiring and receiver de-ghosting marine seismic data includes acquiring seismic trace data recorded from a common shot by at least two seismic streamers, the at least two streamers adjacent to one another in the cross-line direction and vertically offset from one another, the vertical offset at least different enough to record combinations of seismic signal frequencies which are substantially unaffected by receiver-side ghosting, selecting a reference seismic trace from the seismic trace data from a first streamer of the at least two streamers, selecting a candidate seismic trace from the seismic trace data from a second streamer of the at least two streamers, the second streamer adjacent to and vertically offset from the first streamer, the candidate seismic trace being proximal to the reference seismic trace, applying normal move-out (NMO) correction to the reference seismic trace, whereby an NMO target trace is created, applying NMO and vertical datum correction to the candidate seismic trace, whereby a synthesized candidate trace is created; and performing de-ghosting of the NMO target trace by: performing frequency weighted summation of the synthesized candidate trace and NMO target trace, perturbing the synthesized candidate trace with respect to the NMO target trace, the perturbing step further comprising shifting the time of the synthesized candidate trace with respect to the NMO target trace and repeating the frequency weighted summation and perturbing steps to maximize a parameter of the de-ghosted NMO target trace.

[23] According to another embodiment aspect of the present invention, a method for acquiring marine seismic data includes the steps of towing a first set of streamers at a first depth, towing a second set of streamers at a second depth which is different than the first depth, wherein the streamers in the first set of streamers are laterally offset relative to the streamers in the second set of streamers; and acquiring the marine seismic data using both the first and second sets of streamers.

[24] According to another embodiment aspect of the present invention, a method for source de-ghosting of seismic trace data acquired by two shots each received by a streamer includes selecting a

reference seismic trace associated with seismic trace data received by a streamer in connection with a first one of the two shots, selecting a candidate seismic trace associated with seismic trace data received by the same streamer in connection with a second one of the two shots, wherein the second shot of the at least two shots is fired adjacent to and vertically offset from the first shot, the vertical offset at least different enough to input combinations of seismic signal frequencies which are substantially unaffected by source-side ghosting, the candidate seismic trace being proximal to the reference seismic trace, applying normal move-out (NMO) correction to the reference seismic trace, whereby an NMO target trace is created, applying NMO and vertical datum correction to the candidate seismic trace, whereby a synthesized candidate trace is created; and performing de-ghosting of the NMO target trace by: performing frequency weighted summation of the synthesized candidate trace and NMO target trace, perturbing the synthesized candidate trace with respect to the NMO target trace, the perturbing step further comprising shifting the time of the synthesized candidate trace with respect to the NMO target trace and repeating the frequency weighted summation and perturbing steps to maximize a parameter of the de-ghosted NMO target trace.

[25] According to another ~~embodiment~~ aspect of the present invention, a method for source de-ghosting marine seismic trace data includes selecting a reference seismic trace associated with seismic trace data received by a streamer in connection with a first one of the two shots, selecting a candidate seismic trace associated with seismic trace data received by the same streamer in connection with a second one of the two shots, wherein the second shot of the at least two shots is fired adjacent to and vertically offset from the first shot, the candidate seismic trace being proximal to the reference seismic trace; processing the reference seismic trace and the candidate seismic trace; and de-ghosting the processed, reference seismic trace using the processed, candidate seismic trace.

[26] According to another ~~embodiment~~ the disclosure herein, a method for receiver de-ghosting marine of seismic trace data acquired by a shot recorded at a plurality of marine seismic streamers, includes selecting a reference seismic trace associated with the seismic trace data from a first streamer of the plurality of streamers, selecting a candidate seismic trace

associated with the seismic trace data from a second streamer of the at least two streamers, wherein the second streamer is adjacent to and vertically offset from the first streamer, the candidate seismic trace being proximal to the reference seismic trace, applying normal move-out (NMO) correction to the reference seismic trace, whereby an NMO target trace is created; applying NMO correction and vertical datum correction to the candidate trace, whereby a synthesized candidate trace is created, and performing a de-ghosting of the NMO target trace by: performing frequency weighted summation of the synthesized candidate trace and NMO target trace, perturbing the synthesized candidate trace with respect to the NMO target trace; and repeating the frequency summation and perturbing steps to generate a de-ghosted NMO target trace.

[27] According to ~~an embodiment~~ the disclosure herein, a method for source de-ghosting of seismic trace data acquired by two shots each received by a streamer includes selecting a reference seismic trace associated with seismic trace data received by a streamer in connection with a first one of the two shots, selecting a candidate seismic trace associated with seismic trace data received by the same streamer in connection with a second one of the two shots, wherein the second shot of the at least two shots is fired adjacent to and vertically offset from the first shot, the candidate seismic trace being proximal to the reference seismic trace, applying normal move-out (NMO) correction to the reference seismic trace, whereby an NMO target trace is created, applying NMO correction and vertical datum correction to the candidate trace, whereby a synthesized candidate trace is created, and performing a de-ghosting of the NMO target trace by: performing frequency weighted summation of the synthesized candidate trace and NMO target trace; perturbing the synthesized candidate trace with respect to the NMO target trace; and repeating the frequency summation and perturbing steps to generate a de-ghosted NMO target trace.

[28] According to ~~another embodiment~~ the disclosure herein, a method for acquiring marine seismic data includes the steps of towing a first set of streamers at a first depth, towing a second set of streamers at a second depth which is different than the first depth, wherein the streamers in the first set of streamers are laterally offset relative to the streamers in the second set of streamers; and acquiring the marine seismic data using both the first and