

Claims

1. A method for attenuating noise in marine seismic signals, comprising:
cross ghosting pressure responsive marine seismic signals acquired by deploying
5 pressure responsive sensors in a body of water, and contemporaneously acquired motion
responsive marine seismic signals acquired by deploying particle motion responsive
sensors in a body of water, the signals acquired in response to actuation of a seismic
energy source in the body of water;
determining a difference between the cross ghosted signals; and
10 using the difference to attenuate substantially horizontally propagating noise in
at least one of the pressure responsive signals and the motion responsive signals.
2. The method of claim 1 wherein the cross ghosting comprises transforming the
pressure responsive signals and the motion responsive signals into the frequency-
15 wavenumber domain and applying a ghosting operator from the pressure responsive
signals to the motion responsive signals and vice versa.
3. The method of claim 2 wherein the respective ghosting operators are related to a
travel time of seismic energy between a depth of seismic sensors in a body of water and
20 the surface of the body of water.
- ~~4. The method of claim 1 wherein the noise comprises horizontally propagating~~
~~noise.~~
- 25 45. The method of claim 14 wherein the noise comprises at least one of noise from a
vessel and noise from a seismic energy source.
56. The method of claim 45 wherein the seismic energy source noise originates from
a same source used to acquire the pressure responsive and motion responsive seismic

signals.

67. The method of claim ~~41~~ wherein the motion responsive signals are normalized for an angle of incidence of seismic energy.

5

78. The method of claim 1 wherein noise induced in the motion responsive signals by towing seismic equipment in a body of water is attenuated by synthesizing a selected frequency range portion thereof using the pressure responsive signals.

10 89. The method of claim 1 wherein the using the difference comprises determining time samples of the difference that exceed a selected threshold, and setting time corresponding samples of the pressure responsive signals equal to zero.

15 940. A method for seismic surveying, comprising:
towing a seismic energy source and a plurality of pressure responsive seismic sensors and motion responsive seismic sensors in a body of water;
actuating the seismic energy source at selected times;
recording signals detected by the pressure responsive sensors and the motion responsive sensors;
20 cross ghosting the pressure responsive signals and the motion responsive signals;
determining a difference between the cross ghosted signals; and
using the difference to attenuate noise propagating substantially horizontally in the body of water in at least one of the pressure responsive signals and the motion
25 responsive signals.

1044. The method of claim 940 wherein the cross ghosting comprises transforming the pressure responsive signals and the motion responsive signals into the frequency-wavenumber domain and applying a ghosting operator from the pressure responsive signals to the motion responsive signals and vice versa.
30

1142. The method of claim 1044 wherein the respective ghosting operators are related to a travel time of seismic energy between a depth of seismic sensors in a body of water and the surface of the body of water.
- 5 | 13. ~~The method of claim 11 wherein the noise comprises horizontally propagating noise.~~
1244. The method of claim 943 wherein the noise comprises at least one of noise from a vessel and noise from a seismic energy source.
- 10 | 1345. The method of claim 1244 wherein the seismic energy source noise originates from the same source used to acquire the pressure responsive and motion responsive seismic signals.
- 15 | 1446. The method of claim 940 wherein the motion responsive signals are normalized for an angle of incidence of seismic energy.
1547. The method of claim 940 wherein noise induced in the motion responsive signals by towing seismic equipment in a body of water is attenuated by synthesizing a selected frequency range portion thereof using the pressure responsive signals.
- 20 | 1648. The method of claim 940 wherein the using the difference comprises determining time samples of the difference that exceed a selected threshold, and setting time corresponding samples of the pressure responsive signals equal to zero.
- 25 |