

## METHOD AND DEVICE FOR ACQUIRING MARINE SEISMIC DATA

### DESCRIPTION

5 The present invention relates to the gathering of marine seismic data.

More particularly it concerns a method and device for marine seismic acquisition, capable of producing data which can be processed for the elimination of ghost signals.

10 A ghost is a parasitic signal due to reflections of the seismic waves at the water-air interface formed by the surface of the water.

### STATE OF THE ART

15 During seismic surveys, the purpose is to permit the locating of seismic reflectors located at different depths under the seafloor. Reflectors may lie at shallow depths (so-called shallow events), at medium or large depth (so-called deep events).

20 One widespread technique used for oil or gas prospecting consists of conducting a seismic survey of the subsurface. To image the structure of the subsurface, geophysicians use "seismic-reflection" techniques.

In marine seismics, the conventional technique consists of towing behind a vessel:

- one or more energy sources for the emission of acoustic waves, and

5       - seismic receivers arranged on cables called streamers positioned horizontally at a constant depth  $\Delta z$  to record the acoustic wave reflected by the interfaces between geological formations.

The source transmits an acoustic wave to the water, by setting up a wave field (compression waves) which propagates coherently and downwardly (downward propagation) into the subsurface. When the wave field strikes an interface between formations, called reflectors, it is reflected through the sub-surface and water as far as the seismic receivers (upward propagation) where it is converted into electric signals and recorded.

Seismic receivers are arranged so that the recorded signals, called traces, form seismic data which can be used to construct an image of the geological layers.

One problem that is encountered is reverberation, and can be explained as follows. A seismic wave reflected by a reflector passes through the water in a generally upward direction. This wave which is called the "*primary*" propagates in the water and passes through the seismic receiver which records its presence.

The wave field continues its progression towards the surface of the water (whose reflection coefficient is -1) where it is reflected downwards. This reflected wave field or "*ghost*" is also propagated in the water and passes through the receivers where it is recorded once again with reverse polarity and a time lag  $\Delta t$  which, for waves propagating vertically, is:

$$\Delta t = 2\Delta z/c$$

in which:

- $\Delta t$ : the time difference between the recording of the primary wave and ghost respectively by the receiver,
- $\Delta z$ : the distance between the streamer and the water surface,
- $c$ : the rate of propagation of the wave in water (namely 1500 m/s).

10 This reverberation of the seismic wave field in the water affects seismic data by amplifying some frequencies and by attenuating others, which makes reflector location difficult.

15 In the spectral domain, the ghost corresponds to a filter transfer function:

$$G(f) = 1 - \exp(2j\pi f\Delta t)$$

This transfer function  $G(f)$  is zero for multiple

frequencies  $f$  of  $f_n$  in which 
$$f_n = \frac{1}{\Delta t} = \frac{c/2}{\Delta z} = \frac{750}{\Delta z}$$

20 These frequencies for which a transfer function is zero are called "notches". Notches are a particular hindrance since they cannot be deconvoluted.

In the 1980s, data gathering techniques using slanted streamers were proposed. Said techniques are notably described in documents US 4 353 121 and US  
25 4 992 992.

In the first document, a seismic streamer of length 1.2 km is used, having an angle in the order of 2 degrees with the surface of the water.

30 With this configuration, it is the operation of data stacking which ensures the elimination of ghosts. The acquired data is effectively redundant, and the processing method comprises a data stacking step. The recordings contributing towards this stack, which were recorded by different receivers, display notches at

different frequencies, so that the information that is missing due to the presence of a notch on one seismic receiver is obtained from another receiver.

5 A device using a seismic streamer 1 km in length has a limited exploration depth owing to its length, and does not enable the location of seismic reflectors lying several kilometres deep.

10 The streamers currently used in 3D marine seismic surveys, adapted to locate deep reflectors, generally have a length in the order of 6 to 10 kilometres. The principle of a slanted streamer proposed in the above-cited patents cannot be applied to them since, with an angle of 2 degrees, this would lead to a maximum depth of 280 m, whereas in practice a depth of 50 m is  
15 considered to be a maximum. On this account, this principle has not been used since the end of the 1980s.

Since the 1990s interest has focused geological structures at deeper depth.

20 To locate deep reflectors, high frequency acoustic waves are not suitable on account of the high attenuation they undergo during their propagation.

So as to maintain a bandwidth at large depth, comprising a sufficient number of octaves which is the necessary condition for a good image, an octave must be  
25 gained in the low frequencies thereby increasing the conventional bandwidth of 3 octaves 5-40 Hz to a bandwidth of 2.5-20 Hz for example. To do so, it is possible to increase the depth of the streamer. However, it is not sufficient to give priority to low  
30 frequencies since high frequencies are needed to estimate precisely the velocity model of the surface layers.

The signal-to-noise ratio must therefore be improved for low frequency acoustic waves, without this

ratio being deteriorated for the high frequency acoustic waves.

One purpose of the present invention is to propose a technique to acquire marine seismic data which has  
5 broad dynamics with respect to the depth of the reflectors able to be located, and which is simple and efficient with respect to operations and economics.

#### PRESENTATION OF THE INVENTION

10 According to the invention, there is provided a seismic wave acquisition method using at least one streamer towed by a vessel and comprising a plurality of seismic receivers, characterized in that the streamer comprises a head portion in which the depth of  
15 the receivers increases the further they lie away from the vessel, so that said head portion has a first slant angle, and a tail portion comprising at least one section having a second slant different to said first slant.

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#### PRESENTATION OF THE FIGURES

Other characteristics and advantages of the invention will become further apparent from the following description which is solely illustrative and  
25 non-limiting, and is to be read with reference to the appended drawings in which:

- figures 1 and 2 illustrate acquisition devices belonging to the prior art;
- figures 1' and 2' illustrate spectra of a  
30 shallow event, obtained using the devices illustrated figures 1 and 2;
- figures 3 and 4 illustrate two embodiments of an acquisition device according to the invention;

- figures 3' and 4' illustrate spectra of a shallow event obtained using the devices illustrated figures 3 and 4;
- figure 5 illustrates another embodiment of the acquisition device according to the invention;
- figure 6 is a schematic illustrating a method permitting the processing of marine seismic data recorded by the acquisition device of the invention.

#### DETAILED DESCRIPTION OF EMBODIMENTS

With reference to figure 1, a prior art acquisition device is illustrated comprising a seismic streamer towed by a vessel 2. The streamer 1 comprises a plurality of receivers 4a, 4b spaced at regular intervals in the order of a few metres along the streamer. The receivers are usually hydrophones. The streamer 1 is also equipped, as is conventional, with depth control units called birds 5 mounted on the streamer at regular intervals e.g. at around 300 metres from each other. Said depth control birds are commercially available. Each of the birds 5 can be individually adjusted to position the streamer at a determined depth.

In the device shown figure 1, the devices 5 are adjusted at increasing depths starting from the head of the streamer 1, so that the streamer 1 is slanted relative to the surface of the water 3. The seismic receiver 4a the closest to the vessel 2 is positioned at a depth of 7.5 metres, and the seismic receiver 4b lying furthest distant from the vessel 2 (at a horizontal distance which generally lies between 6 and 10 km in currently used acquisition devices) lies at a depth of 37.5 metres. It is noted in figure 1, as in

the other figures, that the representation of the slant is highly exaggerated compared with reality.

Two spectra 10, 20 of final images (after stacking) of a shallow reflector (depth 800 metres) are  
5 illustrated figure 1'.

The first spectrum 10 (called "*ideal spectrum*" in the remainder hereof) is obtained when modelling does not include any ghost. It is therefore the ideal spectrum which would be obtained if the parasitic ghost  
10 signal was fully eliminated in the signals recorded by the hydrophones (traces).

The second spectrum 20 (called "*effective spectrum*" in the remainder hereof) is obtained using the device illustrated figure 1.

15 It is ascertained that these two spectra have very different shapes. In particular, the width of the effective spectrum 20 is smaller than the width of the ideal spectrum 10: the effective spectrum 20 contains less energy for the low frequencies (lower than 10 Hz)  
20 and high frequencies (higher than 60 Hz) than the ideal spectrum 10.

Yet it is precisely within these frequency bands that the signal-to-noise ratio is to be improved.

With reference to figure 2, another acquisition  
25 device is illustrated comprising a streamer 1 towed by a vessel 2. The depth control birds 5 equipping the streamer are adjusted so that the streamer 1 is slanted with respect to the surface of the water 3. This time, the seismic receiver 4a closest to the vessel 2 is  
30 located at a depth of 15 metres and the seismic receiver 4b the furthest distant from the vessel 2 (at a horizontal distance of 8 km or more) lies at a depth of 37.5 metres.

Therefore, the only difference compared with the device in figure 1 concerns the depth of the seismic receiver the closest to the vessel.

5 The advantage of increasing the depth of the seismic receiver the closest to the vessel is to minimize the effect of swell noise which only affects areas close to the surface.

10 The spectra 10, 20 of final images (after stacking) of the same shallow reflector (depth 800 metres) are illustrated figure 2'.

The ideal spectrum 10 is obtained when modelling does not include any ghost. The effective spectrum 20 is obtained using the device illustrated figure 2.

15 Here again it is ascertained that these two spectra have very different shapes, the effective spectrum 20 containing the notch of a receiver at 15 m, lying at 50 Hz, this notch still being present though in attenuated form.

20 The imperfect ghost elimination obtained using the acquisition devices illustrated figures 1 and 2 is related to the depth of the reflector under consideration (800 metres).

25 For a reflector at this depth, the data recorded by the receivers relatively close to the seismic source have an overriding influence in stacking, the distant receivers making a negligible contribution.

30 Therefore, for a shallow reflector, only the recordings of the seismic receivers positioned in the head portion of the streamer (the closest to the vessel) are used.

35 For the devices illustrated figures 1 and 2, this means that the depth dynamics of the receivers, which determine the diversity of the notches, are insufficient for good quality ghost elimination when processing.

With reference to figures 3, 4 and 5, different embodiments of the invention are illustrated. For reasons of simplicity, these figures show only one seismic streamer 1, but in practice current seismic data gathering devices comprise a plurality of streamers 1 (eight, ten or more) towed by the vessel 2, and the invention is applicable irrespective of the number of streamers towed by the vessel.

Each streamer 1 comprises a plurality of seismic receivers 4, typically hydrophones which produce signals when they receive marine seismic waves emitted by an emission source 6 towed by the vessel 2, and activated at regular intervals (represented as a point source but in practice consisting of several parallel lines of air guns), and further comprises depth control birds 5. The streamers are appropriately solid streamers marketed by Sercel under the trademark Sentinel, but the invention is applicable to other types of streamers. The depth control birds can appropriately be devices of Nautilus type (trademark registered by Sercel) which also permit lateral positioning of the streamers, but once again other types of depth control devices can be used to implement the invention. The distances between adjacent receivers 4 are in the order of a few metres, and appropriately the distances between adjacent depth control birds are between 200 and 400 metres.

As known *per se* means are provided, which are not shown, to determine the position coordinates of the source 6 and receivers 4 on each shot fired by the source 6.

Each streamer 1 comprises a head portion 1a and a tail portion 1b. Each portion comprises a plurality of seismic receivers 4. The depth control birds 5 of the head portion 1a are adjusted for respective depths

which increase the further they lie distant from the vessel, so that portion 1a lies at a slant angle relative to the surface of the water 3. In the embodiments illustrated figures 3 and 4, the depth  
 5 control birds 5 of the tail portion 1b are adjusted uniformly so that portion 1b lies horizontal, in other words its slant angle is zero.

These different configurations allow sufficient notch dynamics to be obtained for shallow reflectors,  
 10 using receivers lying at depths that are acceptable in practice.

In the embodiment shown figure 3, the seismic receiver the closest to the seismic source 6 lies at a depth of 7.5 metres. The head portion 1a appropriately  
 15 has a length of between 1 and 3 km, for example of 2 km. The seismic receiver 4 of the first portion 1a that is furthest distant from the seismic source 6 lies at a depth of 37.5 metres. The second portion 1b being horizontal, the receiver 4 of the second portion 1b the  
 20 furthest distant from the source 6 also lies at a depth of 37.5 metres. Evidently this value is only given by way of illustration. The depth can be chosen in each case in relation to particular conditions (depth of the water section, geological characteristics).

25 Figure 3' illustrates two spectra 10, 20 of final images (after stacking) of a shallow reflector (depth of 800 metres).

The first spectrum 10 ("*ideal spectrum*") is obtained when modelling does not include any ghost. It  
 30 is therefore the ideal spectrum which would be obtained if the parasitic ghost signal was fully eliminated from the signals recorded by the hydrophones (traces).

The second spectrum 20 ("*effective spectrum*") is obtained using the device illustrated figure 3.

It is found that elimination of the ghost is indeed obtained, since the effective spectrum 20 follows the ideal spectrum 10. In particular, the effective spectrum 20 has the same behaviour as the  
5 ideal spectrum for the low frequencies and high frequencies.

Figure 4 illustrates an embodiment which differs from the one in figure 3 through the depth of the seismic receiver the closest to the seismic source. In  
10 the case shown figure 4 this receiver lies at a depth of 15 metres.

Figure 4' illustrates the spectra of final images (after stacking) of the same shallow reflector, obtained from the device in figure 4, for the ideal  
15 case and for the effective case.

By comparing the ideal spectrum 10 and the effective spectrum 20, it is verified that ghost elimination has been properly obtained, that the behaviour of the effective spectrum 20 in the low and  
20 high frequencies is similar to that of the ideal spectrum 10, and that the notch at 50 Hz is suitably filled.

To pay heed to hydrodynamic considerations, the slant of head portion 1a is preferably less than 2%.  
25 This avoids setting up turbulence which would be detrimental to the quality of the signals recorded by the seismic receivers. This slant is preferably more than 1% which provides a sufficient range of receiver depths to achieve good quality ghost elimination when  
30 processing.

With reference to figure 5 another embodiment is illustrated in which the depth control birds 5 are adjusted so that the tail portion 1b of the streamer 1, on and after the junction with the head portion,  
35 comprises a section 1c of smaller slant than the head

portion 1a, a section 1d having a slant smaller than that of section 1c and a section 1e having a smaller slant than section 1d. In this embodiment, the seismic receiver the closest to the surface of the water lies at a depth of between 7 metres and 8 metres. According to one variant of embodiment, section 1e may be horizontal i.e. have a zero slant. According to another variant, sections 1d and 1e form a single section of uniform slant.

Other embodiments of the invention can be considered. For example, the tail portion 1b may comprise alternating "up-coming" sections in which the depths of the receivers 4 decrease the further they lie away from the vessel, and "down-going" sections in which the depths of the receivers 4 increase the further they lie away from the vessel (as is the case for sections 1c and 1d in figure 5). The up-coming and down-going sections may be of the same length and have the same slant. As indicated previously, this slant may appropriately lie between 1 and 1.5% and each of the sections may have a length in the order of 1 km. Said arrangement ensures variation in depth of the receivers along the entire length of the streamer, which ensures a diversity of notch frequencies permitting elimination of ghosts on processing, whilst maintaining the depth of the receivers within a suitable range from an operational viewpoint. For example each of the sections may have a length in the order of 1 km and a slant of between 1 and 1.5%.

#### Processing method

Under the present invention, the seismic data are recorded by receivers located at different depths. The methods to process marine seismic data are generally adapted to receivers which all lie at one same depth.

The operation of "datuming" consists of using recorded data to construct data which would have been obtained if the receivers had been at the same depth. The method to process data derived from a slanted streamer described in US 4 353 121 comprises a 1D datuming step which assumes that wave propagation is vertical. Patent US 4 992 992 replaces the 1D datuming of US 4 353 121 by 2D datuming, which takes into account the angle of propagation in the direction of the streamer, implicitly assuming that propagation occurs in the vertical plane passing through the streamer. Additionally, it is limited to the case in which the streamer has a constant slant angle.

Three-dimensional generalisation of the method described in US 4 992 992, replacing 2D datuming by 3D datuming, comes up against y-sampling restrictions of current 3D geometries: modern acquisition geometries have several streamers which sample dimension y, but the sampling pitch (cross distance between 2 streamers) is in the order of 150 m, an order of magnitude that is larger than the distance between 2 consecutive receivers on a streamer (12.5 m).

It is inferred that the methods described in US 4 353 121 and US 4 992 992 are not applicable to an acquisition geometry corresponding to the embodiments of the invention described above.

The processing method given below can be used to obtain an image directly of the subsurface, using data derived from the above-described 3D acquisition taking into account non-vertical directions of propagation.

This method comprises receiving the marine seismic data derived from 3D acquisition, 3D migration of the seismic data and obtaining an image representing the topography of the subsurface.

3D migration per shot point is a modern method to process seismic data, which allows a precise image of the subsurface to be obtained taking wave propagation accurately into account in complex media.

5        Said migration consists of synthesizing the incident wave from information on the seismic source and reflected wave using recorded data.

For migration of "one-way" type the principle is the following.

10        The incident wave  $D$  (i.e. the wave emitted by the source) is assumed to be down-travelling. This incident wave  $D(x,y,z,t)$  is synthesized recursively at depth  $z$ , the down-travelling wave being initialized at the depth of the seismic source  $z_s$ . The incident wave  $D$  at every  
15        depth  $n\Delta z$  is then calculated recursively by calculating the incident wave at depth  $z+\Delta z$  from the incident wave at depth  $z$ .

Similarly, the reflected wave  $U(x,y,z,t)$  is assumed to be up-travelling and is initialized at  $z=z_r$   
20        with the data recorded by the seismic receivers (if all the receivers have the same depth). The reflected wave  $U$  in the entire volume is then calculated recursively by calculating the up-travelling wave  $U$  at depth  $z+\Delta z$  from the up-travelling wave at depth  $z$ .

25        The image of the subsurface is calculated by the time cross-correlation of the two volumes  $D(x,y,z,t)$  and  $U(x,y,z,t)$ .

The altimetry i.e. the fact that the source and the receivers may have non-zero depths (and all  
30        different) may be taken into account by adding the sources and receivers as  $z$  throughout the recursive calculations: for example a receiver at a depth  $z_r$  lying between  $n\Delta z$  and  $(n+1)\Delta z$  is added during the recursive calculation of  $U((n+1)\Delta z)$  from  $U(n\Delta z)$ .

Also, the migration step is appropriately an adapted mirror migration, so-called by analogy with mirror migration and the adapted filter used for signal processing (consisting of convoluting a measurement  
 5  $s(t)$ , perturbed by convolution with a  $h(t)$  filter, by  $h(-t)$  so as to optimize the signal-to-noise ratio.

For mirror migration, the sea surface is used as mirror: instead of "sighting" the seafloor, it is the water surface that is "sighted" to see the reflectors  
 10 located underneath the seismic receivers.

In practice, the seismic data are considered not as having been recorded at the seismic receivers of the streamer, but at an altitude above the water surface equal to the depth of the receiver located at the  
 15 deepest depth, as illustrated figure 6.

One mirror imaging technique using mirror migration is described for example in the publication "*Facilitating technologies for permanently instrumented oil fields*" Dan Ebrom, Xiuyuan Li, and Dwight Sukup,  
 20 The Leading Edge, Vol.19, N°3, pp. 282-285, March 2000.

In this publication, this technique is used for data gathering using seismic receivers located on the seafloor 8a. The principle used is the principle of reciprocity, and fictitious consideration is therefore  
 25 given to sources on the seafloor (at the receiver positions) and of receivers on the surface (at the source positions).

Mirror imaging consists of using the fictitious ghost source to obtain the image, which can be achieved  
 30 by placing the fictitious sources at their mirror position relative to the water surface, the source positions  $(x_s, y_s, z_s)$  being changed to  $(x_s, y_s, -z_s)$ .

Mirror imaging allows better illumination of shallow reflectors.

With respect to adapted mirror migration,  $(x_r, y_r, z_r)$  being the positions of the receivers on the streamers, the reflected wave  $U$  (assumed to be up-travelling) is initialized with altimetry migration at  
 5 an altitude  $-z_{\max}$ ,  $z_{\max}$  being the maximum depth of the seismic receivers (the maximum of all  $z_r$ ) and altitude 0 corresponding to the water surface.

During the recursive downward movement of the wave  $U$  as  $z$  between values  $-z_{\max}$  and 0, the recording of the  
 10 receiver under consideration is added with a sign change at the mirror positions of the receivers relative to the seafloor i.e. at  $(x_r, y_r, -z_r)$ .

Continuing downwards for  $z=0$  to  $z_{\max}$ , the recordings of the receiver under consideration are  
 15 added at their real positions  $(x_r, y_r, z_r)$ . The remainder of the recursive calculation of  $U$ , the generation of the incident wave  $D$  (assumed to be down-travelling) and the cross-correlation step between incident and reflected wave to obtain the image, are conducted in  
 20 similar manner to a conventional one-way migration.

In this manner, the subsurface image is obtained directly from data acquired using the method of the invention, taking into account the exact receiver positions and the exact 3D propagation of the waves.

25 The step, during which recordings are added at the mirror positions of the receivers, provides strengthening of the signal-to-noise ratio by imaging based on the ghost receiver, without doubling the migration calculation time which would be the case if  
 30 two images were calculated and then stacked as proposed in "*Facilitating technologies for permanently instrumented oil fields*". The above-described processing allows an image of the subsurface to be obtained directly from data derived from the 3D  
 35 acquisition according to the invention.

Contrary to the methods described in US 4,353,121 and US 4,992,992 the processing method described above does not comprise any step consisting of reconstructing seismic data, which would have been recorded by a horizontal streamer, using seismic data recorded by the slanted streamer prior to their migration.

The processing method described above takes into account the angles of propagation at both x and y.

This method also makes it possible to improve the signal-to-noise ratio by using ghost data to reinforce primary reflection data.

If the depth diversity of the sensors does not permit full elimination of ghost waves, the resulting perturbation on end data is convolution by a filter that is symmetrical (zero phase) and can be deconvoluted (no notch). This deconvolution step is simplified by the fact that it is a zero phase deconvolution.

The description of adapted mirror migration given above concerns the case of 3D migration for "one-way" shot point. There are other types of migrations which can be adapted as adapted mirror migration by adding to the calculation of the reflected wave, in addition to recordings of the receivers at their exact positions, the opposite recordings at their mirror positions.

There is also a 3D migration per shot point called "Reverse Time Migration" which does not assume that the incident wave is a down-travelling wave and the reflected wave an up-travelling wave. In this case, the adapted mirror migration can be performed by adding the receivers at their effective position  $(x_r, y_r, z_r)$  but by using at the water surface so-called free-surface boundary conditions instead of the usually used absorbing boundary conditions.

In the embodiments described above, the seismic receivers of the streamers are hydrophones. The acquisition geometries described can also be applied when the streamers comprise in combination hydrophones  
5 sensitive to pressure, and receivers sensitive to displacement, such as geophones or accelerometers.

In such a case, the adapted mirror migration processing described above can also be used, keeping in mind that this processing has to be achieved separately  
10 for each type of receiver.

Moreover, the sign change has not to be applied to the records of vertical geophones but only to horizontal geophones. The results obtained in this way can be combined using a calibration operator, tool  
15 known by the man skilled in the art.

**Claims:**

1. A method for acquiring seismic waves in water, the method comprising:  
towing with a vessel at least one streamer including a plurality of seismic receivers, said at least one streamer being equipped with a plurality of birds for controlling its depth in the water, said plurality of birds being spaced apart along a length of the at least one streamer;  
adjusting a first set of the plurality of birds such that the streamer comprises a straight line head portion having a first slope in which a depth of the receivers increases with a distance of the receivers from the vessel;  
adjusting a second set of the plurality of birds such that the streamer comprises a tail portion including at least one straight line section having a second slope different from the first slope, wherein the tail portion comprises at least first and second sections having receivers with a depth that increases with the distance from the vessel, the first section being closest to the vessel and having a slant greater than that of the second section laying furthest from the vessel; and  
recording the seismic waves, which are reflected and/or refracted by a subsurface to be surveyed, with the plurality of seismic receivers while towing the at least one streamer with the straight line head portion having the first slope and the at least one straight line section of the tail portion having the second slope,  
wherein the plurality of receivers are distributed on both the head portion and the tail portion.
2. The method according to claim 1, wherein the straight line head portion is tilted relative to a horizontal line with a slant between 1 and 2%.
3. The method according to claim 1, wherein the straight line head portion has a length of between 1 and 3 km.
4. The method according to claim 1, wherein a seismic receiver closest to a surface of the water lies at a depth of between 7 m and 8 m.

5. The method according to claim 1, wherein the plurality of seismic receivers of the at least one streamer include hydrophones.

6. The method according to claim 1, wherein the plurality of seismic receivers of the at least one streamer comprise a combination of hydrophones and geophones.

7. A method of acquiring seismic waves in water, the method comprising:

towing with a vessel at least one streamer comprising a plurality of seismic receivers, the at least one streamer being equipped with a plurality of birds that are configured to control their depths in the water, the plurality of birds being spaced apart along a length of the at least one streamer; and

individually adjusting the plurality of birds, starting from a head of the at least one streamer, such that depths of the receivers increase with a distance from the vessel and the at least one streamer comprises at least first and second straight line portions with different slopes, each of the first and second portions including corresponding receivers and birds, wherein the second straight line portion comprises at least first and second sections having receivers with a depth that increases with the distance from the vessel, the first section being closest to the vessel and having a slant greater than that of the second section laying furthest from the vessel, and

wherein the receivers record seismic waves, reflected and/or refracted by a subsurface to be surveyed, while the first and second straight line portions have the different slopes.

8. The method according to claim 7, wherein the first portion is tilted relative to a horizontal line with a slant between 1 and 2%.

9. The method according to claim 8, wherein the first portion has a length of between 1 and 3 km.

10. The method according to claim 9, wherein a seismic receiver closest to a surface of the water on the first portion lays at a depth of between 7 m and 8 m.

11. A seismic system configured to acquire seismic waves related to a subsurface to be surveyed, the system comprising:

at least one seismic source towed by, but not directly attached to, a vessel and configured to emit the seismic waves;

at least one streamer;

a plurality of seismic receivers distributed along a length of the at least one streamer and configured to record the seismic waves; and

depth control devices spaced apart along a straight line head portion and a tail portion of the at least one streamer,

wherein a first set of the depth control devices are adjusted so that in the straight line head portion of the at least one streamer, a depth of first receivers increases the further they lay distant from the vessel, the straight line head portion having a first slope relative to a surface of the water, and a second set of the depth control devices are adjusted so that in the tail portion of the at least one streamer, at least one straight line section has second receivers and the at least one straight line section has a second slope different from the first slope, and

wherein the tail portion comprises at least first and second sections having the second receivers with a depth that increases with the distance from the vessel, the first section being closest to the vessel and having a slant greater than that of the second section having furthest from the vessel.

12. The system according to claim 11, wherein the straight line head portion is tilted relative to a horizontal line with a slant between 1 and 2%.

13. The system according to claim 11, wherein the straight line head portion has a length of between 1 and 3 km.

14. The system according to claim 11, wherein a seismic receiver closest to a surface of the water lays on the straight line head portion at a depth of between 7 m and 8 m.

15. The system according to claim 11, wherein the plurality of seismic receivers of the at least one streamer include hydrophones.

16. The system according to claim 11, wherein the plurality of seismic receivers of the at least one streamer comprise a combination of hydrophones and geophones.