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Title: HYDROPHONE CARRIER

#### TECHNICAL FIELD

The present invention pertains to the field of hydrophone arrays used for sonic imaging. Typically these arrays consist of a mechanical structure which locates a plurality of hydrophones with respect to each other. The mechanical structure also provides a convenient means of deploying, using and retrieving the array. Usually some electronic circuitry and other devices are incorporated in the array to facilitate the collection of multiple channels of data, as well as control the array. The common term for these arrays is "streamer" and this term will be used hereafter.

#### BACKGROUND ART

In application, the streamers are usually towed behind a vessel, either a ship or submarine. In active

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sensing, an acoustic noise source insonifies an area and the streamer detects reflections from any targets in the area. In passive sensing the streamer merely "listens" for any noise generated by targets. This invention  
5 describes techniques that may be applied to streamers used in either application.

An axial section of a prior art streamer structure is given in Figure 1 and will be familiar to those skilled in the art. Connector 1 mechanically,  
10 electrically and optically connects each streamer section to the one before it and thence ultimately to the towing vessel. The signal from hydrophone 2 (only one hydrophone is shown) is taken to connector 1 via wires 3. Strain members 4 run from connector to  
15 connector and provide the axial mechanical strength. A core material, either solid or liquid, fills the space 5 to provide buoyancy (and in some cases desirable acoustic properties). The streamer section is enclosed with a continuous skin 6, which protects the in-streamer  
20 components from water ingress.

A critical performance criterion of streamers is the self noise of the streamer. That is, the unwanted acoustic signal that is detected by the hydrophones when the streamer is towed through the water. The self noise  
25 has two major components, that caused by the turbulence generated by towing the streamer through the water (flow noise) and that induced by the vibration of the streamer

structure. A large part of the vibration coupled into the streamer originates from the tow vessel and is transmitted to the hydrophone section via the towing cable and strain members. Other sources of vibration  
5 may also be present, but are usually less important.

The mechanisms which control the level of the two main noise sources are generally in conflict, that is configurations and designs which lead to low vibration induced noise generally produce a higher flow induced  
10 noise level at the hydrophones.

In liquid filled streamers the vibration noise is dominated by a single propagating wave and can be reduced by designing a group of hydrophones which are spaced in the direction of propagation, the spacing  
15 being a function of the wavelength of the propagating wave. The signals from the group of hydrophones are then summed into a single channel and the wave effects thus cancel each other. Although this technique is successful at noise reduction over a limited frequency  
20 range at the design temperature, the performance cannot be sustained for the temperature range over which the seismic streamer has to operate due to changes in the characteristics of the propagating wave. Typically the jacket material has to be changed to sustain the  
25 performance.

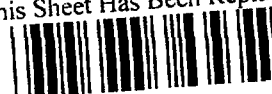
Hitherto, liquid filled streamers have been used since the liquid fill has been shown to have favourable



properties with regard to self noise, but liquid filled streamers are fragile and can be inconvenient in operation. For example, damage to one section of the streamer during steady state towing can lead to a  
5 "knock-on effect" whereby all the sections fail progressively as the streamer sinks. Damage to a section of solid-filled streamer will not necessarily lead to failure of that particular section or any other section and, accordingly, solid-filled streamers are  
10 generally preferred.

Liquid filled streamers are also susceptible to damage during recovery and deployment which is normally achieved by winching. In order to minimise this damage streamers are recovered at low boat speeds and winching  
15 speeds. The low recovery speeds and susceptibility to damage during winching can lead to loss of valuable survey time with a consequent loss of revenue. This becomes more evident when data is being collected using multiple streamers. The use of solid streamers allows  
20 recovery at the normal operating speeds with loss of data only from the streamer being recovered. The recovery time is also reduced by winching at line speeds higher than that which can be achieved with liquid filled streamers.

25 Efforts at replacing liquid filled with more robust solid filled streamers have been frustrated by difficulties in reducing the self noise of solid



streamers to acceptable levels.

#### DISCLOSURE OF INVENTION

5 This invention is primarily concerned with the reduction of vibration induced noise at the hydrophones in a solid filled streamer structure although it is equally applicable to liquid filled streamers. The invention does not require a group of hydrophones to achieve acceptable vibration performance.

10 The robustness of the invention over a range of operating temperatures and handling conditions provides a design to meet a large range of operating conditions.

Furthermore the invention is not limited by the type of transducer and a range of piezo electric  
15 ceramic, piezo electric polymer and fibre optic transducers can be accommodated by the invention.

It is well known that certain transducer configurations produce a low output when vibrated in air. A typical type of transducer which is used in  
20 seismic streamers is a pair of piezo ceramic discs mounted back to back mechanically. These transducers are thus designed for low vibration sensitivity when vibrated in a plane at right angles to the plane of the disc and are intrinsically insensitive when vibrated in  
25 an axis parallel to the plane of the disc. However, this performance is not sustained when the hydrophone is mounted in streamers. The noise levels at the

hydrophone in a streamer are increased due to stresses generated in the solid filler (or pressure in the case of a liquid filler) surrounding the hydrophone. This invention addresses this shortfall by producing  
5 vibration sensitivities close to that of a plain transducer in air.

According to the invention there is provided a hydrophone carrier adapted to mount a hydrophone in a streamer, said carrier consisting of a pair of end  
10 plates spaced apart axially by a rigid or semi-rigid central member or members, thus defining a vibration isolated zone between said end plates. The rigid or semi-rigid central member or members may be arranged in a variety of configurations to allow streamer strength  
15 members and wires to pass through said carrier while allowing said carrier to move axially with relation to said streamer strength members and wires. The streamer is typically encompassed by an outer skin which may be clamped or fixed to said end plates or may be included  
20 as an integral part of said carrier to further reduce vibration within said vibration isolation zone.

To aid in mechanical location of the carrier, the central member of the carrier may be bonded with a relatively compliant material, to the streamer's strain  
25 members. In this case, care must be taken to ensure that the central member of the carrier is sufficiently

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rigid axially and radially to provide the desired isolation.

BRIEF DESCRIPTION OF THE DRAWINGS

5 Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a prior art streamer structure shown in axial section;

10 Figure 2 is a hydrophone carrier according to the invention shown in axial section;

Figure 3 is the hydrophone carrier of Figure 2 shown in situ;

15 Figure 4 is a second embodiment of hydrophone carrier according to the invention shown in situ;

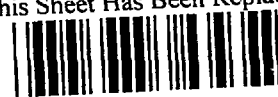
Figure 5 is a third embodiment of a hydrophone carrier according to the invention shown in situ in a perspective view;

20 Figure 6 is a fourth embodiment of a hydrophone carrier according to the invention shown in situ in a perspective view;

Figure 7 is a fifth embodiment of a hydrophone carrier according to the invention shown in situ in cross section;

25 Figure 8 is the hydrophone carrier of Figure 2 incorporating additional devices.

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MODES FOR CARRYING OUT THE INVENTION

The essence of the invention is the means by which streamer structure borne vibration is isolated from the hydrophone by means of a hydrophone carrier.

5 Figure 2 shows an axial cross section through the hydrophone carrier. The carrier consists of a spindle 7, end plates 8 and bosses 9. The carrier is bored through with a hole 10. The bosses 9 help to locate the carrier within the core, but have little effect on the  
10 vibration isolation performance. The bosses 9 have not been shown on all of the remainder of the figures for clarity. An alternative or adjunct to the boss would be to have the hole 10 flared at the ends to locate the carrier within the core.

15 Figure 3, showing a simplified streamer, sectioned axially, exemplifies how the carrier is integrated into a practical streamer. The streamer consists of a central strain member 11 which passes through the length of the streamer. The strain member  
20 11 passes through the hydrophone carrier 12 in which the hydrophone 13 is mounted. The remainder of the streamer is made up of core 14 and skin 15. Not shown are wires for telemetry, control etc. The strain member 11 is attached to the solid core 14 which in turn is adjacent  
25 to the skin 15. It is advantageous for optimum performance that the strain member 11 not be mechanically coupled to the core for a few centimeters



either side of the carrier. In conventional streamer structures such as that shown in Figure 1, vibration at the head of the streamer couples via the strain members 4 and connector plates 1 into the core material 5 of the streamer which is liquid. This then generates a slow speed bulge or breathing wave of high amplitude, compared with the acoustic signals normally received by the hydrophones, thus increasing the overall self noise of the streamer. If the core material 5 is solid the performance is usually worse.

In the structure shown in Figure 3, the hydrophone is isolated from the streamer by the carrier. The strain member 11 is not tightly coupled into the carrier and the hydrophone 13 is isolated from the rest of the streamer by the end plates 8 which are held apart rigidly by the spindle 7. Since the carrier material is considerably more rigid than the core material, the only way for vibration to couple into the hydrophone is by the skin 15. This can be reduced further by placing band clamps 16 around the streamer. Where the material surrounding the hydrophone is fluid, clamps may be necessary to prevent fluid leakage.

The method of preventing the hydrophone mounting from being strained has other benefits which became apparent while testing the invention. The vibration sensitivity of the device is insensitive to temperature variation. This arises because the material (either



solid or gel or liquid) 18 surrounding the sensor is .  
also isolated and hence the material properties cannot  
significantly influence the vibration induced self noise  
levels. Not shown has been the method of mounting the  
5 hydrophone on the carrier. It has been found to be  
advantageous to suspend the hydrophone compliantly  
rather than bond it rigidly to the carrier. A method  
for doing this is to glue soft rubber blocks to the  
carrier and attach a non-sensing part of the hydrophone  
10 to those blocks. For the bender type of hydrophone, the  
non-sensing part is the frame the sensing plates are  
attached to.

The flexibility of the invention is such that by  
spacing the sensors using flexible polymers a situation  
15 is created where the streamer can be winched at the  
normal towing load for seismic operations. The delicate  
sensors are protected from damage during winching by the  
spindle 7 and end plates 8. Further protection may be  
provided by running bars between the peripheries of the  
20 end plates, parallel to the carrier spindle or by other  
means such as a hard "basket" over the sensor.

In the interests of simplicity, the principle of  
the invention has been illustrated using a central  
strain member and omitting the necessary devices and  
25 objects for telemetry and control. It is however  
possible to use a plurality of strain members as shown  
in Figure 4. Here, two strain members 20 and a wire

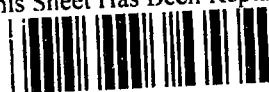


bundle 21 are shown passing through a suitably drilled carrier 22. The principle of isolating the hydrophone from the structure still holds.

The principle of isolation can be extended to  
5 strain members being on the outside of the carrier.  
Figure 5 shows a cross section of the streamer in the middle of the carrier. The isolated part of the streamer is the approximately trapezoidal volume 25. The strain members 26 pass through the carrier on the  
10 side. Locating ribs 27 serve to hold the strain members in place. Devices and objects for telemetry and control 28 may be placed on the streamer axis. With any of the embodiments of figures 3, 4, 6 and 8, it is possible to form a single central core by packaging the wires with  
15 the strength members so that only one axial hole is required in the carrier.

Another method of realising the invention is to make the carrier in the shape of a "horseshoe". As shown in Figure 6, this can then be readily slipped over  
20 the central strain member 11. A block 31 may then be glued or otherwise fastened to the carrier 30 to prevent the strain member from coming out of the carrier.

The efficiency of the carriers may be enhanced by taking advantage of group overlap in practical  
25 streamers. In practical streamers, hydrophones are arranged in groups, a group being a number of (usually) electrically connected hydrophones placed along the



streamer length. These groups are overlapped on practical streamers. In some realisations, hydrophones from overlapping groups may be in the same (or very near) location along the streamer length. In this case  
5 a hydrophone from each group may be placed in the same carrier and the hydrophones connected up to their respective groups. This effects an economy in the number of hydrophone carriers required for a streamer. Of course the same principle may be used to put more  
10 than one hydrophone in a carrier for the same group; this is sometimes advantageous for group design.

Another variation on the design relates to the use of acceleration cancelling configurations which will be illustrated by way of reference to bender  
15 technology. Bender type hydrophones as described earlier have two elements connected back to back to obtain low vibration sensitivity. These elements may be arranged diametrically opposite in the carrier to obtain the same vibration cancelling characteristic.  
20 Alternatively, more elements may be arranged around the circumference of the carrier in other cancelling arrangements, e.g. three elements spaced at one hundred and twenty degrees. These arrangements effect a saving in sensitive material and therefore cost.

25 Figure 7 shows a way of managing the wires and devices for telemetry which may be adapted for use with any of the embodiments described. Figure 7 shows it

specifically adapted for use with the embodiment of Figure 3 by means of an axial cross section through the part of the carrier which contains the hydrophone 13. The strain member 11 passes through the centre as before and the wires and devices for telemetry 33 pass through the axial slots 32. Movement in the wires and devices for telemetry 33 may be accommodated in the slots 32 without affecting vibration performance. This variation is advantageous in terms of incorporating these essential devices in practical streamers. Also shown for illustrative purposes is the streamer's outer skin 15.

Figure 8 shows a way of incorporating devices for amplification of hydrophone signals and/or telemetry in the carrier which may be incorporated into any of the embodiments described. The carrier is shown essentially as in Figure 1 with the addition of modules 33. This variation is advantageous in terms of incorporating these essential devices in practical streamers.

The use of different strain member and carrier configurations provide the opportunity to design, manufacture and repair the streamer by a number of methods.

Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

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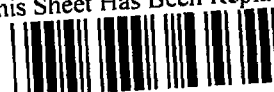




CLAIMS:

1. A hydrophone carrier adapted to mount a hydrophone in a streamer, said carrier consisting of a pair of end plates spaced apart axially by a rigid or semi-rigid central member or members to define a vibration isolated zone between said end plates.
2. A hydrophone carrier according to claim 1, wherein said streamer includes one or more strength members running longitudinally therethrough and said carrier is provided with means to allow said strength member or members to pass therethrough while being mechanically isolated from said strength member or members.
3. A hydrophone carrier according to claim 2, wherein said means comprises a central axial hole formed in said carrier and, in use, spaced from said strength member.
4. A hydrophone carrier according to claim 2, wherein said means comprises one or more slots formed in the outer periphery of said end plates, said slots, in use, being spaced from said strength member or members.
5. A hydrophone carrier according to claim 3, wherein said carrier further includes one or more slots formed in the outer periphery thereof for accommodating connecting wires and/or devices mounted in said streamer.
6. A hydrophone carrier according to claim 1, wherein said hydrophone is mounted to said carrier by compliant mounting means.

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7. A hydrophone carrier according to claim 1, wherein said end plates and said central member or members are formed integrally.
8. A hydrophone carrier according to claim 1, wherein the carrier is formed in two parts, the first part being generally C-shaped in cross-section for, in use, fitting over said strength member or members and a second part being complementary to said first part and fitting into the opening in said first part to prevent removal of said strength member or members from the carrier.
9. A seismic streamer incorporating the carrier of claim 1 or claim 2, wherein said streamer is encompassed by an outer skin and the carrier is fixed to said outer skin of the streamer.
10. A seismic streamer according to claim 9, wherein the carrier is fixed by clamping means positioned circumferentially around the streamer outer skin adjacent said end plates.
11. A seismic streamer incorporating the carrier of claim 2, wherein said carrier is mounted to said strength member or members by compliant mounting means.
12. A seismic streamer incorporating the carrier of claim 1 or claim 2 in which more than one hydrophone is mounted and where the hydrophones are connected to different groups.
13. A hydrophone carrier according to claim 1 wherein acceleration sensitive elements are arranged around the circumference of the carrier to realise acceleration cancelling.