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Inventors: Dandridge et al.
Serial No.:

PATENT APPLICATION
Navy Case No. 75,923

CONTINUOUSLY WRAPPED FIBER OPTIC TOWED ARRAY

BACKGROUND OF THE INVENTION

Field of the Invention

In general this invention describes a fiber optic towed hydrophone array, more specifically a towed array having a series of hydrophones spaced along the length of the towed array structure.

Description of the Related Art

Previously fiber optic towed arrays have been constructed utilizing Fabry-Perot interrogation techniques utilizing a continuous method of wrapping an optical sensing fiber over a specially constructed array structure, as shown in **Figure 1.** The array structure **10** must be chosen such that extensional waves which may be excited by the towing process are not strongly coupled in to the hydrophone units **12**. Further, the individual section of the continuous structure forming the plurality of hydrophone units **12** must be significantly more acoustically sensitive than the interconnect part of the structure so that the noise picked up by the interconnecting optical fibers **14** does not contaminate the acoustical signal response of the array **10** when sensed by the reference interferometer **16**. Additionally, the array **10** must be flexible enough to be capable of being deployed and retrieved by reeling the array **10** around a drum or similar type retrieval device.

Continuously wrapped fiber optic towed arrays have in the past had hydrophones **12** consisting of a single air-backed plastic tube forming the mandrel **18**, as shown in **Figure 2**, and the longitudinal strength member, upon which the sensing optical fiber **14** was wrapped in sections to form each hydrophone. These arrays, because of the longitudinal strength member **18** is a continuous tube which also forms the mandrel for the hydrophone **12**, strongly couples noise due to the towing process into the hydrophone response, completely overwhelming any acoustic signals, which may have been present. This array is not decoupled in any way from the hydrodynamic flow during towing.

SUMMARY OF THE INVENTION

The object of this invention is to provide a towed array providing an acoustic signal with a minimum of hydrodynamic flow noise.

Another object of this invention is to provide a fiber optic towed array that lend itself to continuous construction and is less acceleration sensitive.

This is achieved by having a towed array comprised of a series of rigid acoustically sensitive air-backed plastic mandrel hydrophone devices separated by a distance that allows for the reeling in or out of the towed array. Each hydrophone unit is comprised of one or more series of air-backed plastic mandrel devices wrapped with an optical fiber. Once the optical fiber is wrapped around the mandrels to form the hydrophone device, a cage structure is applied to each unit and the whole array structure is wrapped in a thin layer of open cell foam material. The foam wrapped hydrophone is then placed inside of a hose so as to decouple the hydrodynamic flow noise from the hydrophone during towing.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic of the Fabry-Perot technique for array interrogation as used in the prior art.

Figure 2 is a schematic of the array structure used in the prior art.

Figure 3 is a schematic of the array structure as set forth in the present invention.

Figure 4 is a schematic of a mandrel section of the towed array as set forth in the present invention when a reference fiber is incorporated into the array structure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The continuously wrapped fiber optic towed array **20**, as shown in **Figure 3**, consists of a series of hydrophone **30** devices separated by a distance sufficient to allow for reeling of the complete array **20**. The spacing between the hydrophones **30**, which is dependent upon the desired acoustic frequency, is maintained by a strength member **22** passing through the center of each of the hydrophones **30**. The strength member **22** is chosen such that it does not couple acceleration energy into the array **20**, an example of a strength member **22** would be an aramid rope, manufactured by Gulf Rope and Cordage of Mobile, AL. Each hydrophone **30** unit consists of one or more optical fiber wrapped air-backed plastic mandrel devices (not shown). Within the hydrophone **30**, the optical fiber **23** is split by an input coupler (not shown) into a sensing optical fiber arm, or sensor arm, **23a** and a reference optical fiber arm, or reference arm, **23b**. Upon exiting the hydrophone **30**, the sensing arm **23a** and reference arm **23b** are recombined by an output coupler (not shown) to form the single optical fiber **23** again. The regions between the hydrophone **30** devices may be strain relieved by an aramid rope strength member **22** to ensure that the finished array **10** may be reeled and towed.

Referring now to **Figure 4**, the basic component of the hydrophone **30** is a sensing assembly (not shown). Upon entering the hydrophone **30** the optical fiber is split by an input optical coupler **42a** to form the sensing arm **23a** and reference arm **23b**, as previously stated. The sensing arm **23a** and reference arm **23b** are wrapped onto separate tubular cylindrical air backed plastic mandrels **28** and **32**, respectively. The sensing mandrel **28** nominally has an outer diameter of 0.75 inches and an inner diameter of).625 inches. Nominally the reference mandrel **32** has an outside diameter of).5 inches and an inside diameter of).47 inches. However, the outer may vary from one inch to).625 inches. The reference mandrel **32** is located inside the tube formed by the sensing mandrel **28** and the two mandrels **28** and **32** are separated by a spacer collar **38**, the construction of which is well known to the art. The spacer collar **38** provides an air spacing between the reference mandrel **32** and sensing mandrel **28** comparable to the range of outer diameters of fibers wrapped on the reference mandrel **32** and the inner diameter of the sensing mandrel **28**.

The sensing arm, **23a** is comprised of an optical fiber having a nominal diameter of 165 μm wrapped onto the sensing mandrel **28**, the optimal pitch of such windings being 165 μ/turn. The optical fiber comprising the sensing arm **23a** may have a length between 40 meters and 200 meters dependent upon the sensitivity required and it may be any acceptable optical fiber known to the art, such as, an optical fiber part no. CS 1300 manufactured by Corning, Inc. of Corning, NY.

The reference arm, **23b** is comprised of an optical fiber having a nominal diameter of 165 μm wrapped onto the reference mandrel **32** the optimal pitch of such windings being 165 μ/turn. The optical fiber comprising the reference arm **23b** may have a length approximately equal to the length of the sensing fiber and may be of the same type fiber. By the use of techniques well known to the art, the reference arm **23b** may be eliminated, however, a supporting tube may still be required for the housing of couplers **42a** and **42b** and/or support for the strength member **22**.

At the output, the sensing arm **23a** and reference arm **23b** are recombined into the optical fiber **23** by an output coupler **42b**. Both the input coupler **42a** and output coupler **42b** may be located inside of the tubular cylindrical reference mandrel **32**. This internal area of the reference mandrel **32** may be potted with an epoxy resin, such as Chockfast Orange ®, made by ITW Philadelphia Resins of Montgomeryville, PA.

Once the sensing assembly (not shown) is wrapped with the sensing and reference arm **23a** and **23b**, respectively, a perforated cage structure **24** made of brass, anodized aluminum or stainless steel, is applied over each hydrophone **30** unit. The perforations **24a** allow the acoustic pressure wave to reach the sensing mandrel **28**. A gap of approximately 0.125 inches is formed between the sensing arm **23a** and the cage structure **24**. Endcaps **44a** and **44b**, with penetrations to allow the passage of the strength member **22** and optical fiber **23**, are attached to the input and output ends of the cage structure **24**, respectively. The endcaps **44a** and **44b** fit into the inner diameter of the cage structure **24**. The outer diameter of the cage structure, nominally one inch in diameter, is then wrapped in a thin layer of open cell foam **34**, such as that manufactured by Foam Fair Industries of Aldan, PA, approximately).25 inches in thickness or thicker as required to fill the hose **36**. The foam **34** wrapping continues along the entire length of the array **10** not only covering the cage structure **24** but also covering, but not necessarily touching, the strength member **22** between hydrophones **30**.

The foam **34** covered cage structure **24** is then placed within a hose **36** having a thickness of approximately).25 inches, such manufactured by Raychem Corp. of Menlo Park, CA. The purpose of the assembly formed by the foam **34** and the hose **36** is to decouple the hydrodynamic flow noise from the hydrophone **30** during towing.

With the preferred embodiment of this invention, the overall strength in the array **10** is continuous forming alternating soft (the area between the hydrophones **30**) and rigid (the hydrophones **30**) portions which decouple the vibrations due to acceleration. Each individual sensor assembly (not shown) forming the hydrophone **30** is protected from the foam **34** and the wall of the hose **36** by the cage structure **24** -- physical contact from these items can introduce noise in the hydrophone **30** response. The containing of the array **10** within the open cell foam **34** and hose **36** wall attenuates any noise present due to water flowing past the array **10** during towing, thereby improving the signal-to-noise performance.

The precise dimensions of the various components of the hydrophone **30** sections, the foam **34** and the hose **36** may be varied so as to meet any desired system specification. The number of mandrel units which form each individual hydrophone **30** may be varied in response to array **10** aperture requirements. Multiple layers of optical fiber **23** may be wrapped on each mandrel section to enhance the sensitivity of the finished hydrophone **30**. Multiple array **10** apertures may be formed by wrapping more than one string of fiber optic gratings/mirror (not shown) on the mandrel sections and varying the number of mandrel sections per hydrophone **30** unit. Array **10** shading may be achieved by varying the pitch of the windings on the array **10** structure.

The preferred embodiment of this invention will accommodate not only the Fabry-Perot technique, but such other schemes as the frequency division multiplexing (FDM) or time division multiplexing (TDM) for Mach-Zehnder and Michelson type interferometers. In the case of the other schemes, the necessary couplers and splices may be potted into the centers of the appropriate mandrel sections. While these interrogation schemes do not lend themselves as easily to the continuous wrap construction procedure, they may have superior optical and acoustic performance.

Obviously, many modifications and variations of the present invention are possible in light of the above teaching. It is therefore to be understood that, the invention may be practiced otherwise than as specifically described.

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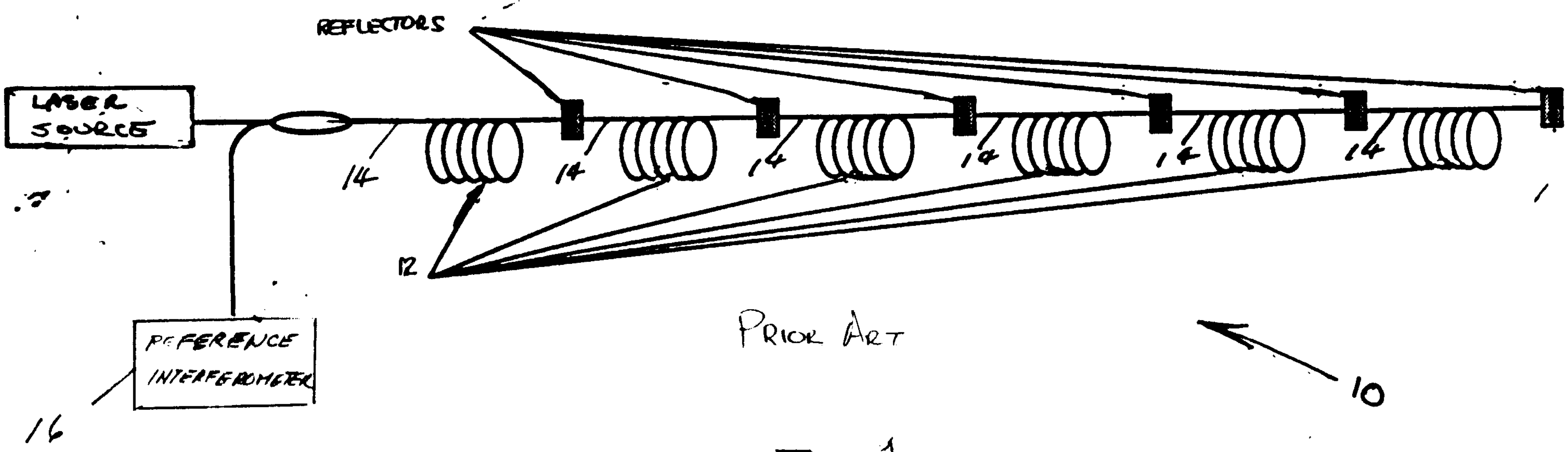
ABSTRACT

A towed array having of a series of rigid acoustically sensitive air-backed plastic mandrel hydrophone devices connected in cascade by a strength member and separated by a distance that allows for the reeling in or out of the towed array. Each hydrophone unit is comprised of one or more series of fiber wrapped tubular cylindrical air-backed plastic mandrel forming a sensing optical fiber arm and a reference fiber arm assembly with the reference fiber arm being located within the sensing fiber arm and separated by an air gap forming a sensing assembly. A cage structure is applied over the sensing assembly leaving an air gap between the sensing fiber arm and the cage forming the hydrophone assembly. The hydrophone assemblies are then wrapped in a thin layer of open cell foam material throughout the array. The foam material and hydrophone structures spaced along the strength member are then placed inside of a hose so as to cover the entire array that acts to decouple the hydrodynamic flow noise from the hydrophone during towing. The overall strength in the array is continuous forming alternating soft (the area between the hydrophones) and rigid (the hydrophones) portions which damp the vibrations due to acceleration. This invention will accommodate not only the Fabry-Perot technique, but such other schemes as frequency division multiplexing (FDM) or time division multiplexing (TDM) for Mach-Zehnder and Michelson type interferometers.



Prior Art

Fig 1

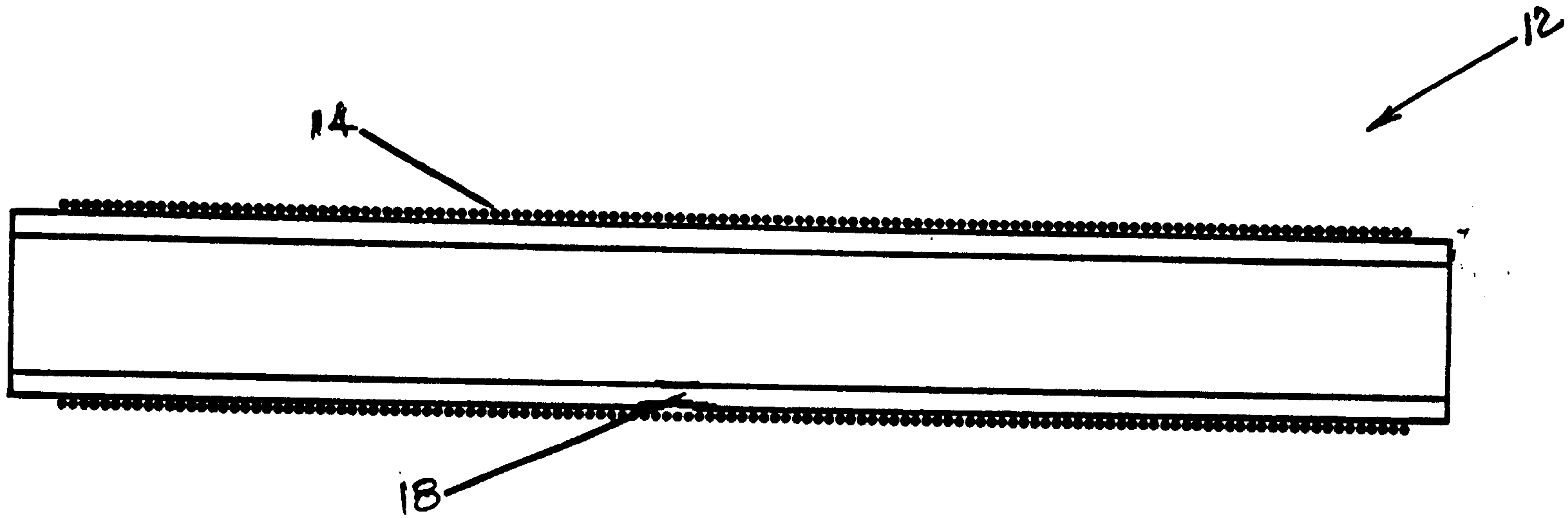
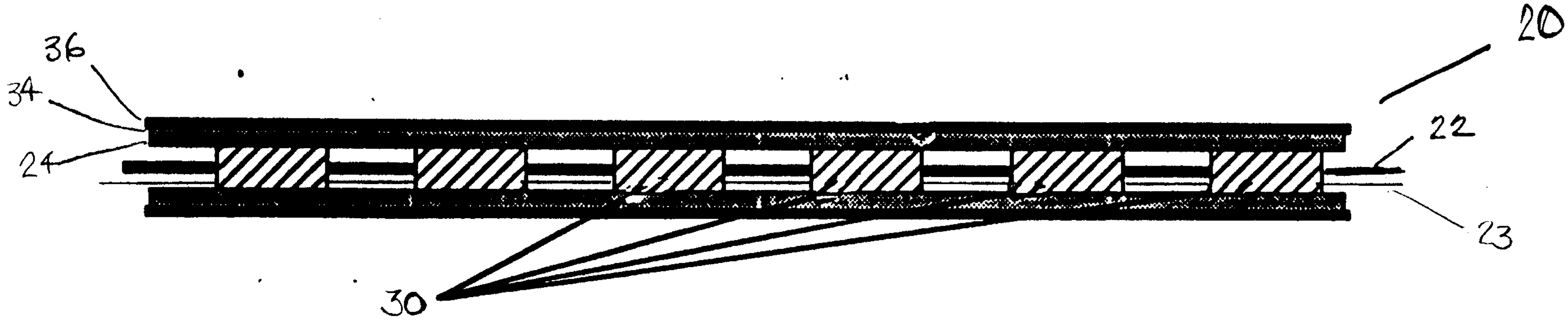


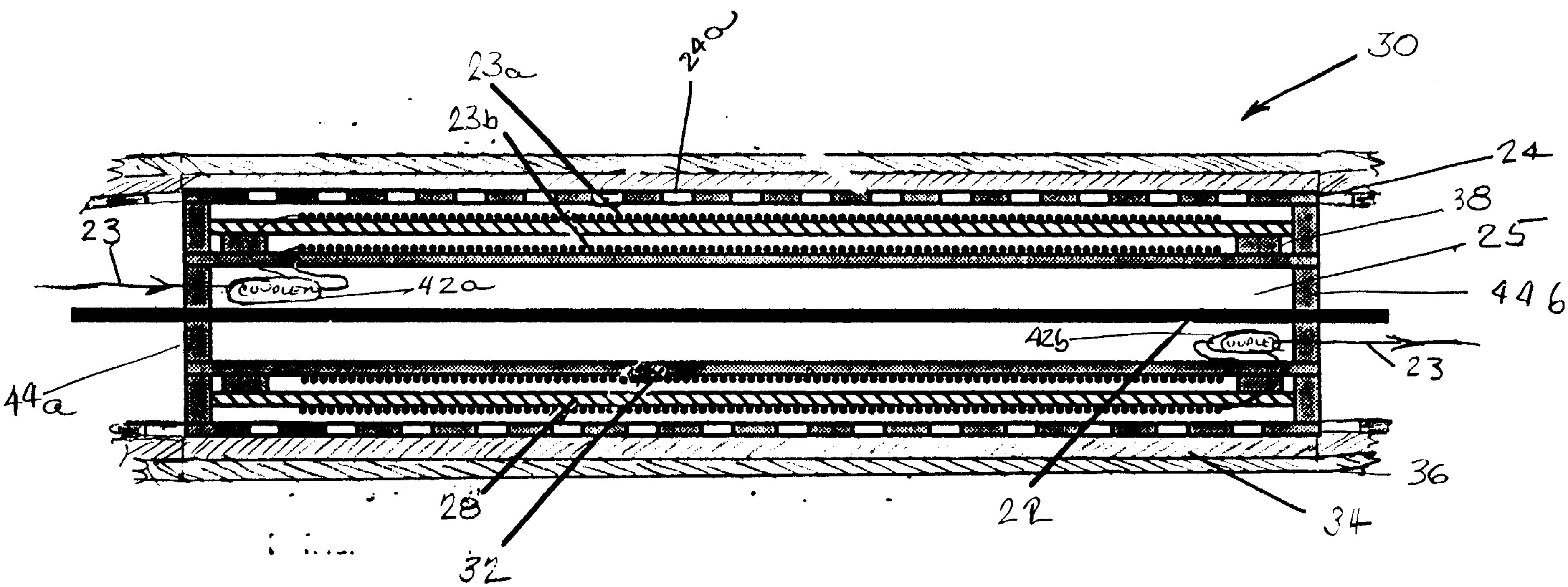
Fig 2

Prior Art



20
22
23
24
30
34
36

Fig. 3



30
24
24a
38
25
44b
23
23a
23b
42a
42b
44a
28
32
22
34
36

Fig. 4