(54) **Method of Classifying Underwater Objects**

(57) Underwater objects are classified by directing upon them from a surface vessel 10 a beam of sound which excites a located object 19 to resonance. Apparatus in the vessel receives the resulting echo signal and derives from it a spectrum of the received frequencies. Classification is effected by comparison of this spectrum with the known frequency spectra of underwater objects likely to be of interest.

Fig.1

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Fig.1
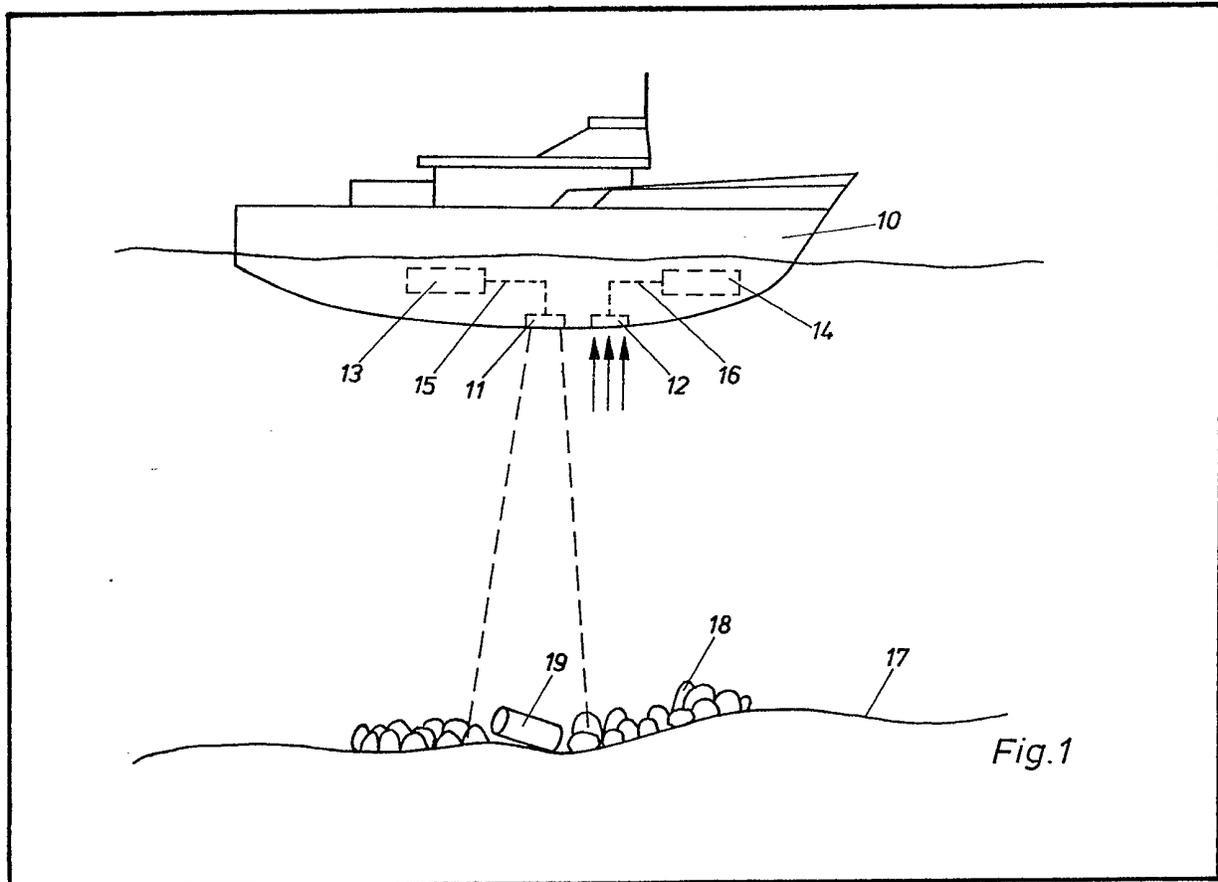
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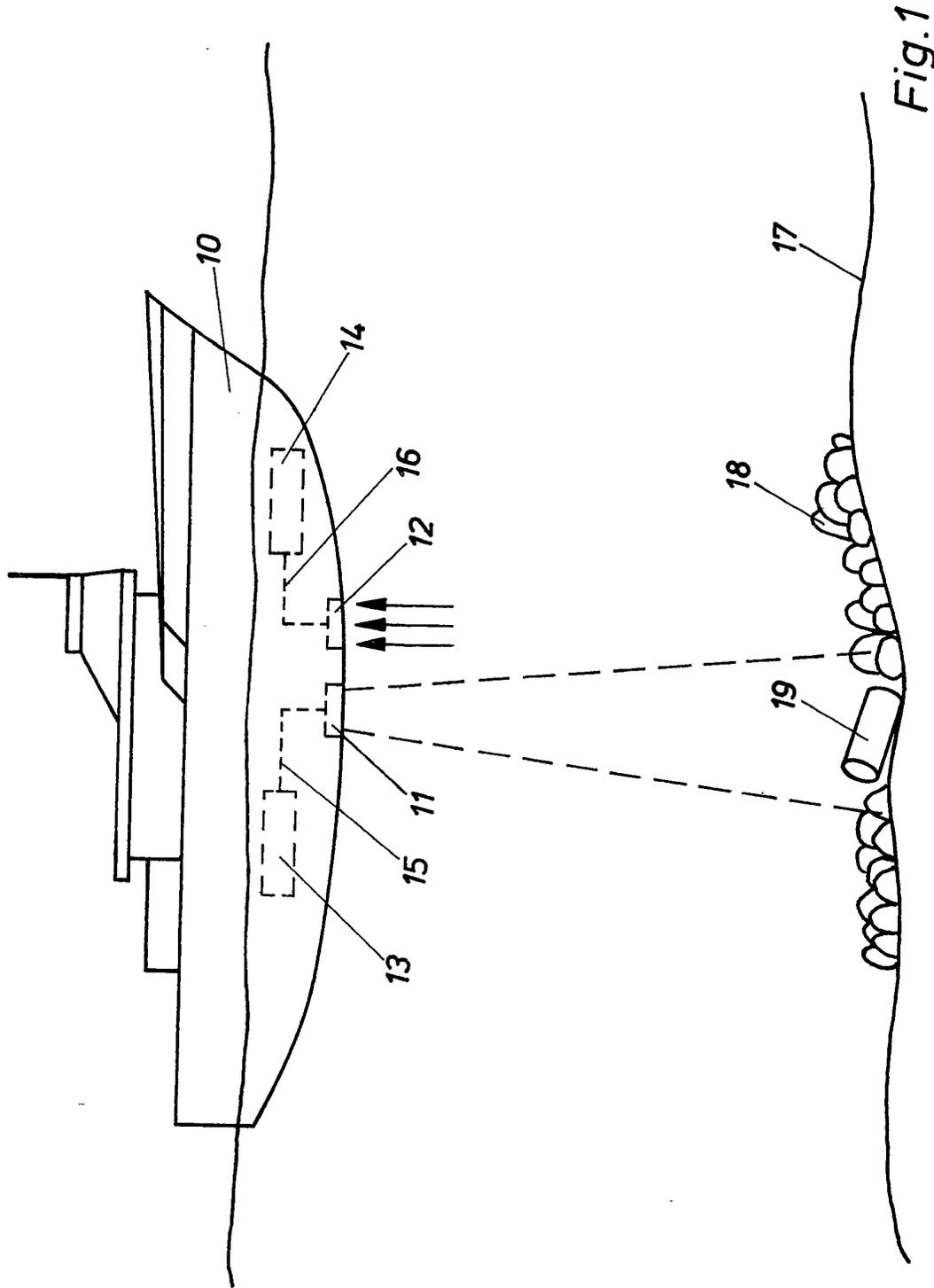
Fig.2

SPECIFICATION
Method of Classifying Underwater Objects

The invention relates to a method of classifying
underwater objects of the kind set out in the
5   introductory portion of Claim 1.
In a known classifying procedure of this kind, a
located underwater object is irradiated by a series
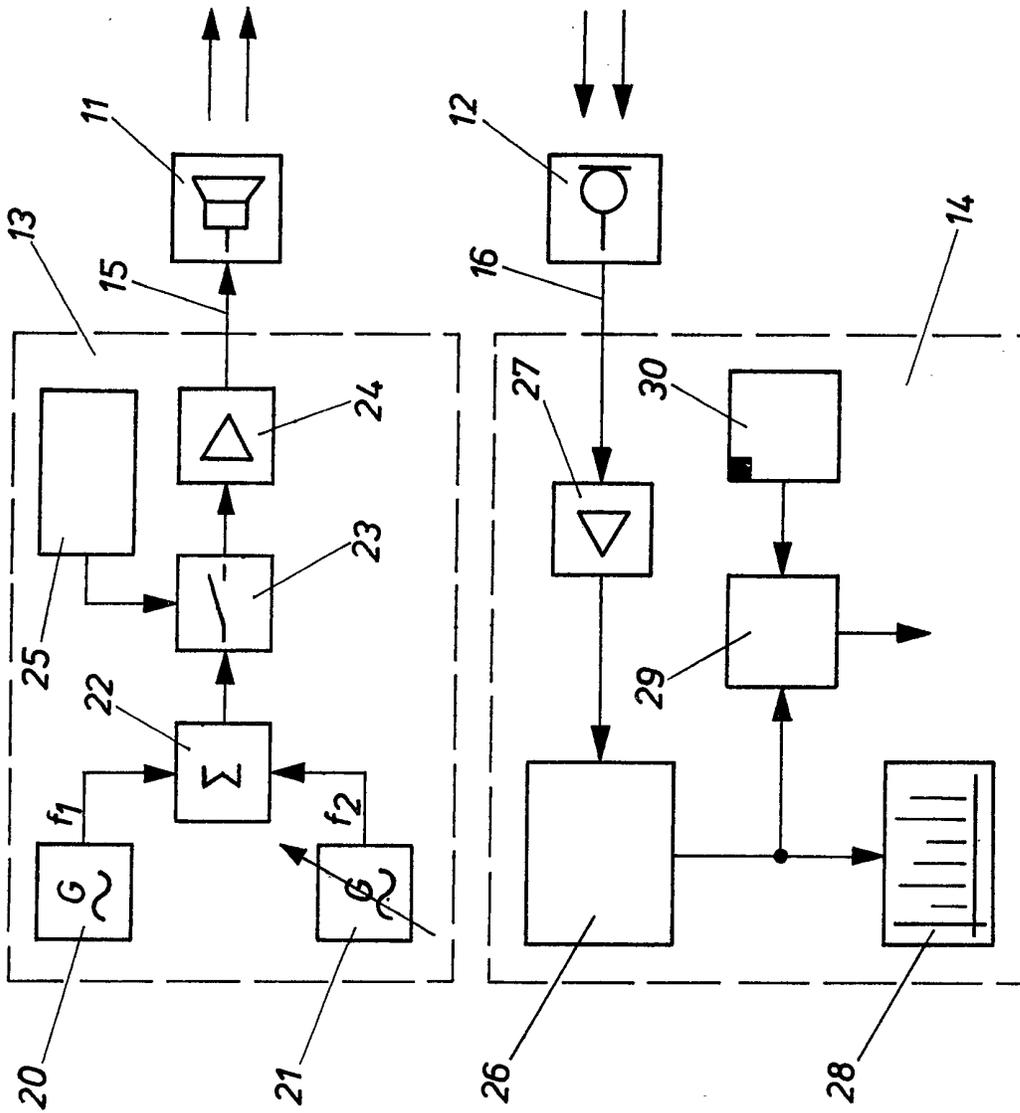of wave trains of constant duration and frequency
(e.g. so called CW pulses), which are reflected
10   from the object and received by a receiver. The
so-called echo signals are utilized to determine
the nature of the object by determining from the
entire structure of the echo signals the external
form of the object which makes its classification
15   possible.
To achieve by this method an echo structure
capable of giving reasonably reliable conclusions
in regard to the located object it is necessary to
use transmitters and/or receivers of high
20   resolution, which is often not possible or only
possible at high cost. Also, owing to the limited
resolution capability of the transmitter and/or
receiver this method is only applicable to
classification of large objects, such as ships' hulls,
25   and not to small barrels, pipe ends or the like.
The object of the invention is to provide a
method of the above kind which makes possible
with limited technical expenditure an effective
classification in particular of small technical
30   underwater objects, such as barrels, pipe ends
and the like, and therefore yields traces of such
objects when located.
This object is achieved in accordance with the
invention in a method of the kind set out in the
35   introduction of claim 1 by the characteristics set
out in the latter part of claim 1.
In the method according to the invention, use
is made of the fact that the so-called "technical"
objects, such as barrels, pipe ends and the like,
40   are distinguished from natural objects of similar
dimensions, such as rocks, pebbles and the like, in
that they have simple forms, smooth surfaces and
generally a constant wall thickness and so have
special patterns of natural frequency. In
45   accordance with the invention these "technical"
objects are excited by acoustic irradiation from a
distance to natural resonance, whereby the
natural or resonance frequencies of the objects
are selectable from the sound energy reflected
50   from the objects and received by the receiver in
accordance with their individual frequency
pattern. For example, it has been determined that
a thick-walled steel cylinder having a length of 40
cm, a diameter of 40 cm and a wall thickness of
55   1.7 cm exhibits 26 natural frequencies in the
range of 0.8 to 8.3 kHz (Acoustics 1979, volume
42, page 93). If this natural frequency pattern of
the underwater object is known, it is possible to
derive from the signals received by the receiver a
60   frequency pattern of selected resonance
frequencies and from these to determine the
nature of the located object. The individual
frequency patterns of the normally limited number
of objects to be classified can be determined,

65   preferably empirically or also by calculation, and
tabulated to afford easy comparison of the natural
frequency pattern in the received signals with
known and recorded natural frequency patterns of
the located underwater objects.
70   The method according to the invention permits
in particular classification of small underwater
objects located at the bottom of a river or the sea
and embedded between stones or in a coral reef.
The resolution of the transmitter and/or receiver
75   need be no greater than in conventional sonar
equipment. The method according to the
invention achieves not only classification of a
located underwater object but also the tracing of
a known underwater object between other
80   objects, e.g. rocks.
An advantageous embodiment of the invention
is given in claim 2. The wide band width of the
sound beam ensures that the range of natural
frequencies of the underwater objects to be
85   classified is fully embraced so that reliable results
are achieved. If one is interested only in tracing
quite definite underwater objects, e.g. pipe ends,
of certain dimensions, it is sufficient to suit the
band width to the range of resonant frequencies
90   of the object sought.
An advantageous embodiment of the invention
is given in claim 6. This measure affords reliable
selection of objects lying relatively close together.
A further advantageous embodiment of the
95   method according to the invention is given in
claim 7. By use of a sonar system operating on
the known parametric principle broad band width
of the sound beam and sharp focussing can be
obtained. The sound beam can consist of a pulse
100   sequence (known as interrupted carrier wave CW
pulses) in which the individual pulses are
modulated at different frequencies, preferably
increasing or decreasing monotonically in the
pulse sequence. The echo signals from the
105   located underwater objects are received in the
intervals between the pulses. It is, however, also
possible to transmit the sound beam continuously
(often called continuous wave signal), this being
composed either of a frequency modulated sine
110   wave signal with monotonic frequency variation
or of background noise or pseudo background
noise.
The invention will now be further described
with reference to an embodiment of apparatus for
115   carrying out the method shown in the drawings,
in which:—
Fig. 1 shows schematically a surface vessel
carrying apparatus for classifying underwater
objects, and
120   Fig. 2 is a schematic block circuit diagram of an
apparatus according to claim 1.
As shown schematically in Fig. 1, a
transmitting transducer 11 and a receiving
transducer 12 are fitted to the keel of a surface
125   vessel 10. The transducer 11 and the transducer
12 are connected by respective electrical
connections 15, 16 to a transmitter 13 and a
receiver 14 disposed inside the ship. Fig. 1 shows
at 17 the bottom of the sea or of a river on which

a "technical" object 19, e.g. a barrel, a pipe end or the like, is embedded between pebbles or rocks 18. The transducers 11, 12, the transmitter 13 and the receiver 14 constitute the apparatus for
5 carrying out the method of classifying underwater objects, referred to below as the classifying device.

In the method according to the invention of classifying an underwater object, e.g. the
10 "technical" object 19 in the form of a barrel or pipe end, the object 19 is acoustically irradiated by the classifying device. A sound beam of very wide band width is used. This is produced by two directional sound beams of different frequency
15 from which, owing to the non-linear transmission properties of water, a frequency is derived corresponding to the difference frequency of the two beams. The transmitter 13 therefore includes a signal generator 20 supplying electrical energy
20 at frequency f_1 and a signal generator 21 supplying electrical energy at frequency f_2, the frequency f_2 being continuously variable. The frequencies f_1 and f_2 are added in an adding circuit 22 and fed to the transmitting transducer 11
25 through a gate circuit 23 and an amplifier 24. The gate circuit 23 is controlled by a timing circuit 25, which switches it on for a determined time, so that the transducer 11 transmits a series of wave trains of determined length, also known as a pulse
30 train, and so transmits sound energy of the frequencies f_1 and f_2 in the non-linear medium, water.

Owing to the non-linear transmission properties of the water, there results in known
35 manner a directional sound radiation having a frequency $f_1—f_2$, which corresponds to the difference frequency of the two sound beams. By appropriate focussing of the two sound beams the resulting radiation can be so focussed that the
40 surface impinged by sound in the locality of the object 19 does not substantially exceed that of the object 19.

Irradiation by sound in this way excites the object 19 to natural resonance. Since the
45 frequency f_2 is varied monotonically for each pulse of the train, the beam of sound striking the object 19 can be varied over so wide a frequency range that it will certainly cover the range in which the object 19 manifests resonance.
50 The object 19 excited to resonance manifests a characteristic natural frequency pattern, which is determined by the material, the dimensions and the wall thickness of the object 19. If the natural frequency pattern of the object 19 is known,
55 classification can take place on the basis of the characteristic resonance frequencies.

The receiver 14 accordingly includes a spectrum analyzer. Such a spectrum analyzer, which operates on the basis of a fast Fourier
60 transformation algorithm, is described in IEEE Transactions on Instrumentation, No. 4, November 1971, pages 198—201.

The sound signals emitted by the object 19 are received by the transducer 12, converted into
65 electrical signals and fed by the conductor 16 to the receiver 14. After passage through an amplifier 27 the electrical signals are applied to the spectrum analyzer 26. This produces a spectrum of the received frequencies in which the
70 resonance frequencies of the object 19 can be clearly recognized. This spectrum is rendered visible on a display 28. Assuming the natural frequency pattern of a large number of possible underwater objects is known, comparisons of the
75 frequency pattern shown on the display with the available known frequency patterns enables the object 19 to be classified as a barrel or pipe end, of determined dimensions. As in practice a limited number of interesting objects is required to be
80 classified, it is possible to determine the frequency patterns of the interesting objects empirically or by calculation and to tabulate them. By successive comparison of the frequency pattern of the located object 19 shown on the
85 display with all tabulated frequency patterns the nature of the object 19 can be specified.

Instead of direct comparison by an operator of the received frequency pattern with known patterns, the receiver 14 may include a computer
90 29 and a store 30, in which the frequency patterns of all known interesting objects are stored. The spectrum of the received signal obtained in the spectrum analyzer 26 is fed to the computer 29, to which the frequency patterns in
95 the store 30 are applied in succession and compared with that from the spectrum analyzer 26. Upon coincidence a signal is given.

The invention is not limited to the above-described embodiment of a method of classifying
100 underwater objects. Thus the sound beam can also be frequency modulated, the frequency being varied monotonically. The sound beam can also be formed of background noise or pseudo background noise.
105 It is also not essential, in the apparatus for carrying out the method, to use separate transmitting and receiving transducers. These may be combined in a single transducer, the conductors 15 and 16 being connected to the
110 transducer through an electrical switch.

Claims

1. A method of classifying an underwater object, in which the object is subjected to acoustic irradiation and determined by the
115 reception of the sound signals generated by the object, characterised in that the object is so irradiated as to excite it to its natural resonance and determination of the object is undertaken on the basis of its characteristic resonance
120 frequencies.

2. A method according to claim 1, characterised in that the object is irradiated by acoustic irradiation of wide band width and preferably by beamed irradiation.
125 3. A method according to claim 2, characterised in that the acoustic irradiation consists of pulse trains, successive pulses of which are modulated by different frequencies, preferably by monotonically varying frequencies.

4. A method according to claim 2, characterised in that the acoustic irradiation is frequency modulated and in that the frequency is preferably varied monotonically and continuously.

5. A method according to claim 2, characterised in that the acoustic irradiation consists of background noise or pseudo background noise.

6. A method according to one of claims 1 to 5, characterised in that the acoustic irradiation is so focussed that its dimensions in the region of the impinged surface of the object do not exceed those of the object itself.

7. A method according to one of claims 1 to 6, characterised in that the acoustic irradiation is produced by two directional sound beams of different frequency so that, owing to the non-linear transmission properties of water, the acoustic irradiation proceeds at a frequency corresponding to the difference frequency of the two sound beams and there is frequency wobbling in at least one sound beam.