

The present invention relates to deployable cylindrical sonars which can be used for example from a helicopter.

5 From the French patent 2 354 920 it is known to produce an acoustic buoy comprising a set of deployable arms on a body, these arms being fitted with hydrophones. When the buoy is released the arms are folded against the body, which facilitates its penetration into the water and avoids tearing off these arms. When it is stabilised
10 in the water at the desired depth, the arms open out in order to give a cylindrical listening base of diameter distinctly larger than the body of the buoy.

A sonar buoy of the same type is also known from patent GB-A-2 093 996, this buoy comprising, on each
15 deployable arm, five columns of hydrophones separated by a distance $\lambda/2$ in order to increase the reception sensitivity. This spacing does not provide any particular characteristic of directivity.

The electronic processing of the signals received
20 by the hydrophones of each arm allows the location of sound sources, for example submarines. However such a cylindrical arrangement, necessarily transparent because of the structure of the device, is the source of a certain number of disadvantages, in particular ambiguities in detection and location arising from the
25 secondary lobes and from the backward lobe of the various hydrophones.

In order to overcome these disadvantages, the invention proposes a sonar according to Claim 1.

30 Other features and advantages of the invention will appear clearly in the following description given by way of non-limitative example with reference to the appended figures in which:

35 - Figure 1 is a perspective view of a sonar according to the invention;

- Figure 2 is a diagram showing the positioning of the columns 4 and 7 of Figure 1;

- Figure 3 is a block diagram of the electronic circuit for the signals coming from these columns.

In the embodiment shown in Figure 1, the sonar comprises a body 1 maintained in a vertical position at the end of a cable 8 which allows it, for example, to be lowered from a helicopter until it is in the water. Around this body are disposed a set of folding arms 2 which are lodged in the folded position in a set of housings 9 located longitudinally along the generatrices of the body 1. Each arm 2 comprises two rods 3 fixed at one end to the body 1 by two hinges 5. A first vertical bar 4 is fixed to the other end of the rods 3 by hinges 6 in order to form, with the rods 3, a parallelogram whose shape can be changed and which is located in the vertical plane passing through the axis of symmetry of the buoy and such that it can be folded against the body and that it can be unfolded into a position in which the rods 3 are horizontal and the bar 4 is vertical. At least one of the rods 3 projects beyond the hinge 6 in order to hold a second bar 7 which is similar to the bar 4. In order to maintain this bar 7 parallel to the bar 4, a cross-piece 10 is used for example, this cross-piece being hinged onto these two bars and located near the ends of the latter which are remote from the hinges 6.

When the arms 2 are unfolded, the bars 4 and 7 of these arms are arranged in two cylindrical vertical rings which are coaxial with the body 1.

By then fitting the vertical bars with transducers, a transparent circular sonar antenna is thus constituted, this antenna being formed by columns of transducers, since there are no obstacles to sound waves between the columns.

In a horizontal plane the bars are grouped in two concentric circles as shown in Figure 2 in the case of 16 arms.

It is known to process the signals coming from the transducers by electronic means, contained for example inside the body 1, in order to obtain in the horizontal plane privileged directions called channels, for transmission or reception. In Figure 2 the directions of channels V_4 and V_5 have been shown for example.

According to the invention, the signals from the two columns of transducers of each arm are also processed by electronic means in order to obtain, for each of these pairs of columns, a pattern in the shape of a cardioid in the horizontal plane. This cardioid can, depending on the case, be oriented towards the outside of the circle like the cardioid 200 shown by a solid line, or towards the inside of the circle like the cardioid 300 shown by a dotted line. For each of the pairs of columns there is thus obtained the electronic equivalent of an elementary antenna said to be baffled in one direction or the other, that is to say an antenna placed in front of a screen which forms an obstacle to reception from the rear and gives this cardioid-shaped directivity.

The electronic processing used in order to obtain this cardioid-shaped directivity can be obtained for example by means of the circuit shown in Figure 3.

If the two columns of one arm are separated by a distance d , the signal received in the direction θ with respect to the alignment of these two columns will be $s_c(t)$ for the column 7 and $s_i(t)$ for the column 4.

The two signals $s_c(t)$ and $s_i(t)$ are added in a first adder 30. They are phase shifted by $\pi/2$ in two phase shifters 40 and 50, and the signals thus phased shifted are subtracted in a second adder 60. The signal from the adder 60 is multiplied by a coefficient β in a multiplier 70 and then the signal obtained is added in an adder 80 to the signal coming from the adder 30.

If $A \cos \omega t$ is the received signal, the resultant signal $x(t)$ supplied by the adder 80 is equal to:

$$x(t) = 2 A \cos \omega t \left[\cos \left(\frac{\pi d}{\lambda} \cos \theta \right) + \beta \sin \left(\frac{\pi d}{\lambda} \cos \theta \right) \right]$$

where λ = the operating wavelength of the sonar,
 $\beta = \cotan \left(\frac{\pi d}{\lambda} \right)$ for the outer cardioid (200) and

$\beta = - \cotan \left(\frac{\pi d}{\lambda} \right)$ for the inner cardioid (300).

If d is small compared with λ , and at the very least less than $\lambda/4$, the formula reduces to:

$$x(t) = 2A \cos \omega t (1 + \cos \theta).$$

It is therefore noted that the smaller d becomes, the closer the shape comes to a cardioid. There is however a limitation due to the sensitivity to spread in the characteristics of the transducers, which increases with the value of the coefficient β .

It is known to form a channel aimed in a given direction by delaying (or phase shifting) the signals from the sensors of an antenna by a value corresponding to the phase resetting of the signals following this direction and then by adding them.

By then appropriately combining the signals thus processed for all the pairs of columns there is obtained the equivalent of two half-cylindrical baffled antennas oriented along the desired channel, one being concave and the other convex, which considerably reduces the disadvantages due to the transparency of the structure of the antenna, by greatly reducing the level of the signal received from the rear.

For this purpose, according to the invention, each channel is formed by summing the signals from the hydrophones of each column supplying the two signals $s_1(t)$ $s_o(t)$, and then by taking the signals corresponding to the cardioids oriented towards the outside ($+\beta$) for all the pairs of columns located on the same side with respect to a diameter perpendicular to the direction of the channel, that is to say a half in the described example, and by taking the signals corresponding to the cardioids oriented towards the inside ($-\beta$) for the other half.

This is simply obtained by means of a selection device at the level of the circuit 70.

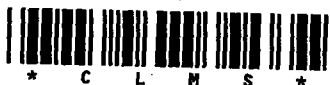
By way of example, in order to obtain the channel V_4 in Figure 2, the outer cardioids are used for the arms 1 to 8 and the inner cardioids are used for the arms 9 to 16. Similarly, for channel V_5 , the outer cardioids are used for the arms 2 to 9 and the inner cardioids are used for the arms 10 to 1.

With regard to the directivity in elevation of the sonar, which is related to the length dimension of

the columns 4 and 7, it is possible to substantially improve it by weighting, in a known way, the spatial distribution of the elementary transducers within each of the columns. In a way which is also known, it is possible to replace this spatial weighting by an electronic weighting of the transducers which are then regularly spaced along the bar.

As a numerical example of embodiment, for a sonar operating at 3.5 kHz, it is possible to use a mean diameter for the two rings of columns of 1m with a spacing, d , between these rings of 7cm, distinctly less than $\lambda/4$, and a column height of 60cm.

The invention is not limited to the case in which the columns are located in a ring forming a cylinder with a circular base since, in a known way, the formation of channels can be produced by electronic means for columns disposed on cylinders whose bases form all kinds of curves such as ellipses or various polygons. Similarly, in addition to being attached to a helicopter, the sonar can be attached to a surface ship or can even form a possibly retrievable acoustic buoy.



Claims

1. Deployable cylindrical sonar, of the type comprising a cylindrical body (1), a set of arms (2) hinged onto the body and each bearing a set of columns (4, 7) of transducers, the arms being able to be folded against the body and to be deployed by placing the columns parallel to each other along the generatrices of a set of virtual cylindrical surfaces, and means of processing the signals from the hydrophones in order to form at least one transmission and/or reception channel (V_4), characterised in that the arms (2) each bear two columns (4,7) separated by a distance which is less than a quarter of the operating wavelength of the sonar, in that the processing means furthermore comprise means of giving to each pair of columns of each arm a directivity in reception and/or in transmission which is substantially cardioid and oriented towards the inside (200) or towards the outside (300), and in that they also comprise means of selecting, at the channel formation level, a section of the pairs of double columns whose cardioids are oriented towards the inside and the other section of pairs of double columns whose cardioids are oriented towards the outside, thus simulating two antennas, one of them concave and the other convex, oriented in the direction of each channel formed, all of the pairs of columns being used in order to form each channel.

2. Sonar according to Claim 1, characterised in that the columns (4,7) are regularly distributed in the deployed position over two cylindrical surfaces having coaxial circular bases and in that for each channel formed the processing means respectively select the cardioids located on one side of a diametral plane of the cylinder perpendicular to the direction of the channel (V_4) and the cardioids located on the other side of this diametral plane.