

SPECIFICATION

Electro-acoustic equipment for the underwater detection and identification of a vessel

- 5 The invention relates to an electro-acoustic equipment for the underwater detection and identification of a vessel and is intended to prevent, during armed conflict, untimely underwater attack on neutral vessels, hospital ships, health-service vessels, rescue vessels and generally those craft protected by the Geneva Conventions, such protection being afforded by the emission of an underwater acoustic signal.
- 10 The main object of the conventional submarine service is always that of destroying the merchant tonnage of the enemy or enemies so as to achieve a maritime blockade. The nature of anti-submarine warfare and the activities of underwater vessels require that these vessels remain deeply submerged, maintain silence on board and, by means of passive sonars, listen for underwater noises in their patrol zone. After a target has been detected, it is destroyed by
- 15 different types of torpedo, for example of the cable-guided and acoustic types, which have ranges of up to twenty-five nautical miles. In these circumstances the detection and identification of a possible target are achieved solely by sound and practically never by sight; certainly, a submarine can hardly be allowed to surface with its periscope down because of the great danger of being detected and rapidly destroyed. When moving, a vessel emits various underwater
- 20 noises e.g. the whirr of its propellers, the noise of the main and auxiliary engines, the wash along its stern and vibrations due to its advance through the water. This noise forms the basis for detecting and identifying vessels by submarines with the aid of passive sonars. These latter are directional listening networks which cover the horizon sector by sector. They consist generally of hydrophones, compensation networks, amplifiers and various systems for process-
- 25 ing signals. They are in the charge of trained operators who listen to the noises that are picked up and are aided by automatic indicators which have been developed largely to suit the various marine nations and the class of submarine. As a rule, listening by trained operators is the simplest method and is in general use in all types of submarines.
- 30 An increase in the noise level at the output of the passive sonar at a given bearing leads to the detection of a possible target. The spectral characteristics of the signal (acoustic signature) permit a friend or an enemy to be detected and enable the type of craft to be identified (cargo vessels, submarine chasers, fighting vessels, etc.).
- Although, in theory, it is possible to identify any vessel by its acoustic signature, in practice this can only be achieved in the case of certain known vessels or types of vessels of each
- 35 maritime nation.
- In particular, it is practically impossible to differentiate between, on the one hand, neutral transport vessels and those protected by the Geneva Conventions, and, on the other hand, transport vessels belonging to the enemy. In the event of war, the first-mentioned vessels will be regarded as non-friendly and will therefore run a very grave risk of being sunk without warning.
- 40 In these circumstances, a naval power will be able to exercise a total maritime blockade against neutrals and the hospital services by claiming that it is impossible to guarantee immunity to their vessels in view of the submarine danger.
- Such a situation is grave for neutrals, and in particular for Switzerland, whose supplies by sea route would be dangerously threatened or even cut off in the event of a crisis or armed conflict.
- 45 Furthermore, because of this bias, neutrals would be subjected to intolerable political pressures by the belligerents.
- Hitherto, no underwater acoustic signalling and identification system has been developed and used. It will be remembered, however, that in 1917, an agreement between the belligerent nations had provided that allied hospital ships should be accompanied by paddle vessels. Their
- 50 particular acoustic signature enables hospital ship convoys to be identified by German submarines. In 1972, at the Conference of government experts regarding the reaffirmation and development of international human rights regarding armed conflicts, the International Red Cross Committee dealt with the signalling and identification of hospital ships. The problem of protection against underwater attacks was discussed in a technical memorandum (Geneva, April
- 55 1972). It was there suggested that an audible underwater signal having a suitable pitch should be sent out. Australian experts proposed the introduction into the technical appendix of the Geneva Conventions, a new clause relating to underwater acoustic signalling of the presence of hospital ships. The context of this clause is as follows:—
- 1 Ships and places of embarkation concerned with hospital services could be identified by a
- 60 signal transmitted by a multi-directional sonar.
- 2 The strength of the emitted signals was to be at least equal to that radiated in the water in the emission frequency band by vessels in question at their maximum cruising speed.
- 3 The signal was to be transmitted sequentially at frequencies of 3, 6 and 12 kHz and was to consist of the letters HS (Hotel Sierra) in morse code and transmitted three times at each
- 65 frequency, each group of three transmissions being followed by a continuous signal of five

seconds at the same frequency. The transmission cycle would be repeated at intervals of two minutes maximum.

This proposal has not yet resulted in the setting up of a signalling system, and on the basis of calculations carried out by the present Applicants, this system would not be able to operate satisfactorily.

The present invention seeks to provide equipment for enabling submarines to identify ships by the emission of an underwater acoustic signal. By installing such equipment and other identification means aboard its ships (to prevent attacks by air, by surface craft or by coastal batteries), a neutral state would be able to claim immunity for vessels at sea, while at the same time submitting them to the controls associated with a possible blockade. The principle and construction of the proposed equipment are such that it can be used only for the purpose of signalling the presence of and identifying the vessel using it. It therefore cannot be used for detecting and determining the position of submarines.

In accordance with the invention there is provided electro-acoustic equipment for the underwater detection and identification of a vessel, said equipment comprising an emitter having at least one electro-acoustic transducer mounted on the hull of the vessel so that, when the vessel is afloat, it is submerged, and an electronic circuit for controlling the or each transducer such that, in use, it emits, at audio-frequency, an identification signal specific to the vessel and constituted by a series of letters or figures emitted in code and preceded by a start-of-emission signal, said identification signal being emitted at at least one frequency selected for each vessel and within the sound spectrum of the noise created by the vessel itself, but above spot noise occurring at discrete frequencies within the spectrum and different from the harmonics of such discrete frequencies and wherein the emitter and its control circuit are so rated that the signal is emitted at a strength such that the level of acoustic intensity LI_s (dB), by unit of distance, of the identification signal of mean frequency f_s (Hz), is greater than or equal to the sum of:

- (i) the level of acoustic intensity LI_b , by unit of distance, of the sound band, centred on the frequency f_b (Hz), resulting in the detection of the vessel by its particular underwater noise in the ambient background noise of the sea; and
- (ii) a parameter Δ the value of which in decibels is calculated by means of the relationship:

$$\Delta = 40 \alpha_s + 10 \log \frac{B_{cs}}{B_{cb}} - 15 \log \frac{f_s}{f_b} + 6,$$

wherein α_s = the coefficient of absorption of sound in the sea at the frequency f_s ,

B_{cs} and B_{cb} (Hz) = the critical screening bands at the frequency f_s and f_b respectively.

Preferably the frequency of the emitted signal lies in the range 4 to 6 KHz. Satisfactory results have been obtained by the applicants for values of 7, 14 and 19 dB for corresponding emission frequencies of 4, 5 and 6 kHz.

The emission circuit is preferably designed to produce, in code, signs representing figures and letters the duration of which is in the range 100 to 800 ms, the gaps between signs being about 800 ms and the gaps between groups of signs, which represent a figure or a letter, being about 1600 ms.

The identification signal may be in Morse code, the dot signs having a duration of about 200 ms, and the dash signs a duration of about 700 ms.

The circuit may be so designed as to produce an emission signal at two frequencies f_1 and f_2 differing from each other by several tens of Hz, up to 200 Hz, the uneven signs in the succession of signs forming the signal being transmitted at the frequency f_1 and the even signs forming the signal being transmitted at the frequency f_2 .

In a preferred embodiment, the emitter comprises four transducers arranged in a square, the control circuit having switches adapted to connect the transducers two by two in opposite phase in two times four successive arrangements, each forming a sequence, so as to cover the horizon in two times four emission sectors, a complete signal code being emitted for each two by two arrangement, with intermediate pauses.

The emitter is preferably mounted in a water-tight case in the bottom of the vessel above a window formed in the hull, the transducer or transducers being positioned vertically with their emission diaphragms substantially in the plane of the opening in the hull.

The control circuit of the emitter preferably comprises an impulse generator functioning as a timer and connected to a sequencer controlling the sequence of operations terminating in the formation of the coded signal, said sequencer itself being connected with the emitter through an encoder producing at least one signal-emission frequency, and through an amplifier, the generator being connected to a controller for enabling all the emission parameters to be selected. The encoder is preferably connected to the amplifier through a signal conditioner which transforms the square impulses produced by the encoder into sinusoidal impulses, and

switching relays for the transducers are arranged between the amplifier and the emitter, the relays being controlled by the sequencer connected directly to the controller.

It will be seen that the equipment in accordance with the invention enables a submarine to identify the vessel carrying said equipment, since the frequency of the identification signal is within the spectrum of the noise from the ship, preferably between 4 and 6 KHz, which will be detected by the submarine. In fact, submarines carry at least one passive listening sonar having a frequency generally ranging from 500 Hz to approximately 7 kHz. They generally have several sonars which enable the frequencies of from 100 to 50,000 Hz to be covered. Consequently, as soon as the submarine begins to detect the presence of a ship, the identification signal will reach it, since said signal is emitted at a frequency different from the vertical lines (spot frequencies) of the vessel's noise spectrum and from their harmonics (corresponding to the machine noises within the ship), so that the signal is not confused with or masked by these lines or their harmonics. On the other hand, the strength of the emitted signal should be reduced as much as possible so as to limit the space occupied by, and the cost of, the emission means, but the signal should be strong enough for it to be always detected and recognised when the ship is detected by its own underwater noise (noise caused by forward movement of the ship, wash, propellers etc.) in the surrounding basic noise from the sea, under conditions which are less favourable for the signal and more favourable for the characteristic noise.

The accompanying drawings illustrate, by way of example, an embodiment of electro-acoustic signalling and identification equipment in accordance with the invention, and they also include sketches explaining the signals and codes used and the underwater phenomena in relation to the operation of the equipment.

In the drawings:

Figure 1 is a diagram illustrating the general nature of the typical spectrum of the characteristic underwater noise emitted by a surface vessel at a distance of at least several hundred metres;

Figure 2 illustrates in graph form a basic signalling and identification code of a particular ship, the code being formed by letters emitted in Morse;

Figure 3 is a vertical section through an electro-acoustic emitter comprising four transducers set up in the double bottom of a ship carrying the equipment, the emitter sending out its signalling and identification emission through a hole formed in the hull for this purpose;

Figure 4 is an underneath view of the emitter shown in section in Fig. 3, and shows the four electro-acoustic emission transducers mounted on a base-plate forming part of a water-tight case solidly connected to the hull of the vessel in which the emitter is set up;

Figure 5 is an explanatory sketch illustrating how the horizon is swept by the emission of the signalling and identification code in four successive sectors representing an emission sequence; and

Figure 6 is a block circuit diagram relating to the control of the transducers illustrated in Figs. 3 and 4.

Before proceeding to a description of the embodiment of the signalling and identification equipment, some explanations will first be given in connection with technical considerations of which the described embodiment is based.

The principle on which the signalling and identification equipment is based, consists in the periodic emission in Morse of an identification code containing the call sign of the ship carrying the equipment. The emission is carried out by all or nothing modulation of a wave maintained at audio-frequency. The frequencies, strengths, durations and rhythm of the Morse signs of the emitted code are the characteristic parameters of the equipment. They have been determined on the basis of the two following criteria:

The identification code must of necessity be recognised by a submarine when the latter detects the underwater noise typical of the ship equipped with the apparatus.

The emission strength must be as low as possible so as to reduce the space occupied by, and the cost of, the equipment, and to enable the equipment to be installed in small vessels, but the emission strength must be great enough to meet the first criterion.

The parameters are determined by calculations, simulation and tests, the following factors being taken into consideration:

1 The underwater noise of the vessel itself, the spectrum of which is illustrated in Fig. 1. The typical spectrum is composed of a continuous part 1 (noise from wash, forward movement and propellers) and of lines 2 (noise from main and auxiliary engines) corresponding to discrete frequencies and diminishing with frequency. As illustrated in Fig. 1, the noise due to the forward movement of the ship and represented by the line 1 is made up of frequencies of up to 20 kHz. The vertical lines 2 representing the noise of the main and auxiliary engines within the hull generally have frequencies that are greater, the higher the speed of the ship or the lower its tonnage. On the other hand, these lines 2 always have harmonics that have to be taken into account. Following numerous calculations and tests, the Applicants have reached the conclusion that the emission-frequency band of the identification signal should be between 4 and 6 kHz.

This frequency band is represented at 3 in Fig. 1.

2 Identification of a vessel: the acoustic signature of a vessel consists mainly of the lines of the spectrum of the noise from the vessel itself. It is however, obvious that these lines should be known so that the vessel can be identified. The emission of a recognition signal in the noise spectrum of a vessel itself is therefore indispensable for confirming the acoustic signature of said vessel, the more so since this signature may vary as a function of the external conditions as explained below.

3 Underwater propagation of the sound: the hypothesis of normal propagation causes the intervention of a decrease in sound by geometrical divergence (the r^{-1} or r^{-2} factor, where r is the distance from the source), and attenuation by absorption; the latter increases exponentially with the distance r , and rises rapidly with the frequency of the sound.

4 Irregularities in propagation: because of propagation conditions in the sea (reflection from the bed and the continuously moving surface, curving of the sound radiations due to bathythermy), the acoustic signal picked up at a given point undergoes considerable changes in level (similar to the fading of radio-electric waves in the atmosphere); in particular, a signal of short duration at emission (for example the dots and dashes of a Morse code) may result in the reception of two signals or even more; thus, a dash may be repeated by a strong echo and will be interpreted, on reception, as being two dots; a dash may be divided into two parts and interpreted as being two dots or a dash and a dot, or a dot and a dash, etc.

5 Masking of the identification code: in order to be detected and identified by a trained operator or an automatic analyzing device, within the noise associated with the ship carrying the equipment or the ambient background noise (noise from the sea-bed), the code, on reception, must have an intensity depending upon its frequency and the spectra of the masking noises.

As a function of the criteria and conditions defined above, the identification code C is illustrated in Fig. 2 and is formed in the following way:

The basic code C, representing the identification signal in the 4 to 6 kHz frequency band, is composed of a start-of-transmission signal and the call sign of the ship carrying the equipment, which signals may be repeated a second time. The start-of-transmission signal - . . . facilitates identification of the dash-dot Morse signs, the durations and relationship of which are different from those used in telegraphy, since they depend upon the conditions imposed by the underwater propagation of sound. As an example, Fig. 2 shows the code of the Swiss motor vessel Regina, the radio call sign of which is H B D R. The code C will be used and emitted in Morse on the frequency band having a total range of 4 to 6 kHz. The durations of the Morse signs is 200 ms for the dots (.) and 700 ms for the dashes (-). The gaps between signs are 800 ms, and between letters 1600 ms. In order to take account of particular propagation conditions, these durations are programmable and can be varied in increments of 100 ms between 100 and 800 ms for the dots and dashes, and of 200 or 400 ms between 200 and 3200 ms for the gaps.

For each vessel, two different emission frequencies f_1 and f_2 will be selected in the 4 to 6 kHz band and will differ from each other by several tens of Hz up to 200 Hz. Quite clearly, they will be selected as a function of the acoustic signature of the vessels to be fitted with the equipment (Fig. 1) so as not to fall within the lines 2 of the spectrum or within their harmonics, and choice will also take into account the dimensions and space occupied by the emitter. For each sign (dot or dash) of the code C, a series of sinusoids of adequate duration is emitted in turn at the two frequencies f_1 and f_2 . The series of signs of the uneven kind are emitted at the f_1 frequency, and those of the even kind at the f_2 frequency. Emission is stopped between two signs for a period corresponding to the sign space of the letter space.

To avoid having to use a high-power multi-directional emitter, the emission is directed with a directivity axis which is variable in a stepwise manner. The entire horizon is then covered sector-by-sector by sequential switching of the directivity axis, a complete code being emitted in each position.

An emission sequence S is constituted by a certain number of codes C separated by pauses P (periods of silence) or programmable duration (10, 20, 30, 40 and 60 s). For example, for scanning the horizon in four sectors, the emission frequency consists of four codes C and of three pauses P, i.e.: C-P-C-P-C-P-C. The manner in which the horizon is scanned in four sectors will be explained below with reference to Fig. 5.

The emission of a sequence S is entirely automatic. A time base enables the number of sequences per hour to be set at 1, 2, 3, 4 or 8. For a maximum range of 40 km, the emission strength P_s must be such that

$$L_{s_i} \geq L_{b_i} + \Delta, \text{ (dB)},$$

wherein L_{s_i} is the level of acoustic intensity, converted to unit distance, of the identification signal of mean frequency f_s (Hz); this level L is defined as the minimum in the emission directions corresponding to the intersections of the directivity lobes adjacent the

emitter, in the case of surface scanning sector by sector.

LI_{bi} is the level of acoustic intensity, converted to unit of distance, of the sound band centred on the frequency f_b (Hz), resulting in the detection, at a great distance, of the vessel carrying the equipment, by its characteristic underwater noise, in the ambient sea-bed noise.

LI_{si} and LI_{bi} are expressed in decibels in relation to the reference intensity I_r , equal to 6.5 nW/m^2 in underwater acoustics.

Δ is a parameter, the value of which in decibels, and which is calculated by means of the general formula:

10

$$\Delta = \Delta\varphi \cdot r + 10 \log \frac{B_{cs}}{B_{cb}} - 15 \log \frac{f_s}{f_b} + \Delta M - \Delta D, (\text{dB})$$

10

15 wherein $\Delta\alpha$ (dB/km) is the difference between the sound-absorption characteristics in sea-water at the frequencies f_s and f_b , 15

r (km) is the maximum range for detecting the vessel carrying the equipment, by a frequency band centred on f_b , by the characteristic underwater sound of the vessel, in the surrounding background noise of the sea,

20 B_{cs} and B_{cb} (Hz) are critical masking bands having frequencies f_s and f_b respectively 20

ΔM (dB) is the difference between the perception conditions at the frequencies f_s and f_b of a signal in an output sound from a passive sonar, and

ΔD (dB) is the difference in the directivities of a passive sonar at the frequencies f_s and f_b

25 Taking into account a maximum required range of 40 km and of the most favourable situation 25 for the detection of the vessel and the least favourable situation for receiving the identification signal, the following simplified practical formula is obtained:

$$30 \Delta = 40 \cdot \alpha_s + 10 \log \frac{B_{cs}}{B_{cb}} - 15 \log \frac{f_s}{f_b} + 6, \quad 30$$

wherein B_{cs} , B_{cb} , f_s and f_b are as above, and α_s is the coefficient of absorption of the sound in the sea at the frequency f_s .

35 By way of example, when $f_b = 1 \text{ kHz}$ and for frequencies f_s of 4, 5 and 6 kHz, the values 35 obtained for Δ are 7, 14 and 19 dB respectively.

However, the emission strength must be limited so as to avoid cavitation opposite the transducers. In particular, in the case of a small depth, the vessel will adopt a cruising speed so as to reduce NI_{bpl} , emission strength being limited.

40 Figures 3, 4 and 5, respectively, illustrate an electro-acoustic emitter 5 and a cabinet 40 containing the control circuits 6 of the emitter 5. The emitter 5 is located in the double bottom of the vessel carrying it, and radiates directly into the sea through an opening 7 (Fig. 3)

formed in the hull 8 for this purpose. The control cabinet containing the circuit 6 (Fig. 6) is situated in the machine room or in associated areas or in any other area having the required

45 conditions. It is connected, on the one hand, to the electric power system aboard the vessel 45 and, on the other hand, to the electro-acoustic emitter by means of suitable electric supply lines 30 (Fig. 3).

The emitter 5 comprises four electro-acoustic transducers 10, 11, 12 and 13 disposed vertically; the speaker faces of the transducers face the sea-bed, are arranged in a square and 50 are each supplied separately by respective electric lines 30 running from the cabinet containing 50 the control circuits 6. The four transducers form an emission system. The configuration of this system (distance between axes, supply-voltage phases) is so selected as to provide the various required directivities at the envisaged working frequencies. By switching the supplies of the transducers, directivity variable in a stepwise manner and covering the horizon sector by sector 55 is achieved. 55

Fig. 5 illustrates how the supplies of the four transducers 10 to 13 are switched to as to emit the complete identification codes in accordance with the arrangement shown in Fig. 2 and successively, in dependence upon four different axes. As shown in the sketch of Fig. 5a, the two transducers 10 and 11 are supplied in phase opposition, that is to say using a 180° phase 60 displacement represented by the signs + and -. There is then obtained an emission in the 60 two directions in accordance with the direction represented by the line 14 in Fig. 5a. The entire code C representing the signal in Fig. 2 is emitted, and then the control circuit of Fig. 6 alters the switching of the transducers in accordance with the sketch of Fig. 5b. After this switching change, the code C is again emitted in the two directions of the line 15 in Fig. 5b. Between the 65 two emissions there is a pause as described above. Next come successive emissions with 65

intermediate pauses in the directions shown in Figs. 5c and 5d, the four codes emitted as shown in Fig. 5a to 5d representing a sequence. In the second sequence of the four codes as in Figs. 5e, 5f, 5g and 5h, emission again takes place along the same four axes, but with different transducers. In fact, in Fig. 5e, emission takes place along an axis 16 parallel with the axis 14

5 of Fig. 5a, with the transducers 12 and 13 instead of the transducers 10 and 11. This manner of switching enables the times during which each transducer is used to be balanced so as to avoid excessively rapid ageing of one transducer as compared with another. At the end of the two sequences of four codes each, the Fig. 5a connection is arrived at, and the cycle starts again. The sequences described make it possible, with the aid of four transducers switched two

10 by two, to scan the horizon in four sectors in accordance with the four axes illustrated in Fig. 5, while ensuring that the signal is sent out in a satisfactory manner all round the vessel emitting it. However, it will be obvious that the horizon can also be scanned with a greater number of transducers switched in two by two or three by three. All combinations are possible, and the only limiting factors are cost and space.

15 It will also be obvious to the expert that an emitter consisting of three transducers switched two by two or alternatively supplied in combinations of one transducer, then two, etc. may also be satisfactory. In the extreme case, a single transducer can be used. Then it will be obvious that the main vertical emission component, directed downwardly, will be lost. Therefore, a single transducer would of necessity have to be of much greater power in view of the fact that a

20 considerable portion of its emission power is directed towards the sea-bed and is completely lost.

In the case where a single transducer is used, it is also possible to place it horizontally on a device, not illustrated, designed to rotate through 360° about the vertical.

A combination of four transducers such as has been described in the arrangement shown in Figs. 3 to 6 has given excellent results, since the fact that these transducers are connected two

25 by two in phase opposition results in substantially horizontal emission components.

The emitter 5 is mounted in a circular opening formed in the double bottom of the carrier vessel and preferably in a water ballast. It is located approximately in the rear third of the ship and at such lateral distance from the keel that suffices to prevent its being damaged by keel

30 blocks when the vessel is in dry dock or on a floating dock.

Figs. 3 and 4 show typical arrangements relating to the construction of the emitter 5. In this example, the four transducers 10 to 13 are type TR-61A electro-acoustic transducers supplied by Messrs. Massa. These are piezo-electric transducers which are commercially available. It goes without saying that any other transducer having similar or superior characteristics may be

35 used. The transducers are mounted vertically on a base-plate 21 (Figs. 3 and 4). Seen from below (at the side facing the sea), the speaker faces of the transducers are, as stated above arranged to form a square, the lateral distance d between adjacent transducers being small as possible in view of the problems relating to the construction of the layout. The circular opening

40 7 (Fig. 3) is cut in the hull of the vessel, and its edge is reinforced by a ring 22. The baseplate 21 is secured to the ring 22 by means of screw-bolts 23. Two positions are possible: in the first, the sides of the squares formed by the transducers are parallel with and perpendicular to, respectively, the longitudinal axis of the vessel. In the second position, the diagonals of this square occupy these positions. An intermediate ring 24 is placed between the reinforcing ring

45 22 and the baseplate 21 so as to create a distance e between the speaker faces of the transducers and the outer face of the hull 8, said distance being between 25 and 35 mm. The emitter 5 is surrounded by a water-tight case 25 welded on to the reinforcing ring 22 and closed off by a cover 27 with the aid of screw-bolts 26. A water-tight joint 28 is fitted between the case 25 and the cover 27. When the emitter is not being used, a removable protective plate 29 is bolted into the opening 7 in the hull 8. Electrical lines 30 supplying the transducers 10 to

50 13 pass through the water-tight case in glands 31 and extend to the electronic control cabinet, not illustrated, by way of a protective pipe 32 and the pipework tunnel of the vessel. The transducers 10 to 13 are finally held against the baseplate 21 by means of bolts 33 after having been introduced into cut-away portions 34 (Fig. 4) previously provided in the plate 21 and corresponding to the lower periphery of the transducers; these cut-away portions are of

55 frusto-conical section which is carefully machined so that they can be closely fitted around the transducers so as to ensure that the emitter is water-tight. As illustrated in Fig. 3, the transducers 10 to 13 are also held at their upper portions by a frame 35 which is solidly attached to the plate 31 by means of bolts 36, the distance between the plate 21 and frame 35 being maintained by means of spacers 37. The lines 30 are interconnected within the case 25

60 with the aid of water-tight connecting means 9.

The dimensions and construction of the assembly will vary from case to case as a function of the available space and the requirements of the rating companies.

The block diagram shown in Fig. 6 illustrates the functional structure of the circuits 6 of the electrical control cabinet.

65 A supply unit 41 is connected to the ship's supply system 40 by way of circuit-breakers and

switches, not illustrated, and supplies the various voltages required for operating the equipment and the circuits. A controller 42 enables the user to control the system and to set the emission parameters; it is provided with switches and push-buttons, not illustrated, certain of these being directly accessible on a front panel and others not. The controller 42 permits the selection of the duration of the Morse signals emitted (dot, dash), the duration of the pauses between each code, the duration between sequences, etc.

An encoder 45 is connected, on the one hand, to a generator 43 and, on the other hand, to a sequencer 44, and generates a series of square signals whose frequency alternates between f_1 and f_2 , and whose duration and rhythm correspond to the signalling code C to be emitted. This latter is contained in a store which is specifically programmed for each vessel and which cannot be changed or modified at a later stage.

An interface unit 46 energizes relays 50 under the control of the sequencer 44.

A signal conditioner 47 transforms the square waveform signal from the encoder 45 into a sinusoidal signal, the amplitude of which is controlled by a control device 49.

An amplifier 48 provides the active power required by the emitter and offsets its reactive power by means of suitable reactances.

The control device 49 enables the power supplied to the emitter to be controlled by acting on the gain of the signal conditioner 47. It also protects the amplifier 48 from overload, for example, due to a short circuit.

The relays 50 energised by the interface unit 46 provide for switching of the supplies of the emitter transducers so as to effect sequential scanning of the horizon sector by sector as described in connection with Fig. 5.

Fans 51 keep the amplifier 48 cool.

The entire system is in the form of drawers, not illustrated, accommodated in a metal cupboard, also not illustrated. The cupboard has ventilation inlets fitted with dust filters. The controller 42, the generator 43, the sequencer 44 the encoder 45 and the interface unit 46 are designed in accordance with digital techniques, whereas the signal conditioner 47 and the control device 49 are designated in accordance with analogue techniques.

These components are constructed with the aid of analogue and digital integrated circuits and discrete electronic and electrical members provided on replaceable printed circuits.

The supply unit 41, the amplifier 48 and the relays 50 are constructed with the aid of readily obtainable electronic, electric or electro-mechanical components.

It will be understood that it is possible, as technology develops, to modify the design of the circuits, in particular by making use of a micro-processing system for the entire digital part.

CLAIMS

1. Electro-acoustic equipment for the underwater detection and identification of a vessel, said equipment comprising an emitter having at least one electro-acoustic transducer mounted on the hull of the vessel so that, when the vessel is afloat, it is submerged, and an electronic circuit for controlling the or each transducer such that, in use, it emits, at audio-frequency, an identification signal specific to the vessel and constituted by a series of letters or figures emitted in code and preceded by a start-of-emission signal, said identification signal being emitted at at least one frequency selected for each vessel and within the sound spectrum of the noise created by the vessel itself, but above spot noise occurring at discrete frequencies within the spectrum and different from the harmonics of such discrete frequencies and wherein the emitter and its control circuit are so rated that the signal is emitted at a strength such that the level of acoustic intensity LI_{si} (dB), by unit of distance, of the identification signal of mean frequency f_s (Hz), is greater than or equal to the sum of:

(i) the level of acoustic intensity LI_{bi} , by unit of distance, of the sound band, centred on the frequency f_b (Hz), resulting in the detection of the vessel by its particular underwater noise in the ambient background noise of the sea; and

(ii) a parameter Δ the value of which in decibels is calculated by means of the relationship:

$$\Delta = 40 \alpha_s + 10 \log \frac{B_{cs}}{B_{cb}} - 15 \log \frac{f_s}{f_b} + 6,$$

wherein: α_s = the coefficient of absorption of sound in the sea at the frequency f_s ,

B_{cs} and B_{cb} , (Hz) = the critical screening bands at the frequencies f_s and f_b , respectively.

2. Equipment according to claim 1 wherein the emitted frequency is in the range 4 to 6 kHz.

3. Equipment according to claim 2 wherein the electronic circuit and the emitter are operable to emit a signal having a strength corresponding to values of Δ of 7, 14 and 19 dB for corresponding frequencies of 4, 5 and 6 kHz.



switches, not illustrated, and supplies the various voltages required for operating the equipment and the circuits. A controller 42 enables the user to control the system and to set the emission parameters; it is provided with switches and push-buttons, not illustrated, certain of these being directly accessible on a front panel and others not. The controller 42 permits the selection of the duration of the Morse signals emitted (dot, dash), the duration of the pauses between each code, the duration between sequences, etc.

An encoder 45 is connected, on the one hand, to a generator 43 and, on the other hand, to a sequencer 44, and generates a series of square signals whose frequency alternates between f_1 and f_2 , and whose duration and rhythm correspond to the signalling code C to be emitted. This latter is contained in a store which is specifically programmed for each vessel and which cannot be changed or modified at a later stage.

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The relays 50 energised by the interface unit 46 provide for switching of the supplies of the emitter transducers so as to effect sequential scanning of the horizon sector by sector as described in connection with Fig. 5.

Fans 51 keep the amplifier 48 cool.

The entire system is in the form of drawers, not illustrated, accommodated in a metal cupboard, also not illustrated. The cupboard has ventilation inlets fitted with dust filters. The controller 42, the generator 43, the sequencer 44 the encoder 45 and the interface unit 46 are designed in accordance with digital techniques, whereas the signal conditioner 47 and the control device 49 are designated in accordance with analogue techniques.

These components are constructed with the aid of analogue and digital integrated circuits and discrete electronic and electrical members provided on replaceable printed circuits.

The supply unit 41, the amplifier 48 and the relays 50 are constructed with the aid of readily obtainable electronic, electric or electro-mechanical components.

It will be understood that it is possible, as technology develops, to modify the design of the circuits, in particular by making use of a micro-processing system for the entire digital part.

CLAIMS

1. Electro-acoustic equipment for the underwater detection and identification of a vessel, said equipment comprising an emitter having at least one electro-acoustic transducer mounted on the hull of the vessel so that, when the vessel is afloat, it is submerged, and an electronic circuit for controlling the or each transducer such that, in use, it emits, at audio-frequency, an identification signal specific to the vessel and constituted by a series of letters or figures emitted in code and preceded by a start-of-emission signal, said identification signal being emitted at at least one frequency selected for each vessel and within the sound spectrum of the noise created by the vessel itself, but above spot noise occurring at discrete frequencies within the spectrum and different from the harmonics of such discrete frequencies and wherein the emitter and its control circuit are so rated that the signal is emitted at a strength such that the level of acoustic intensity LI_s (dB), by unit of distance, of the identification signal of mean frequency f_s (Hz), is greater than or equal to the sum of:

(i) the level of acoustic intensity LI_b , by unit of distance, of the sound band, centred on the frequency f_b (Hz), resulting in the detection of the vessel by its particular underwater noise in the ambient background noise of the sea; and

(ii) a parameter Δ the value of which in decibels is calculated by means of the relationship:

$$\Delta = 40 \alpha_s + 10 \log \frac{B_{cs}}{B_{cb}} - 15 \log \frac{f_s}{f_b} + 6,$$

wherein: α_s = the coefficient of absorption of sound in the sea at the frequency f_s ,
 B_{cs} and B_{cb} , (Hz) = the critical screening bands at the frequencies f_s and f_b , respectively.

2. Equipment according to claim 1 wherein the emitted frequency is in the range 4 to 6 kHz.

3. Equipment according to claim 2 wherein the electronic circuit and the emitter are operable to emit a signal having a strength corresponding to values of Δ of 7, 14 and 19 dB for corresponding frequencies of 4, 5 and 6 kHz.



4. Equipment according to any one of claims 1 2 or 3 wherein the electronic circuit and the emitter are operable to produce, in code, signs representing figures and letters, the duration of which is in the range 100 to 800 ms, the gaps between signs being about 800 ms and gaps between groups of signs, which represent a figure or letter, being about 1600 ms.
- 5 5. Equipment according to claim 4 wherein the electronic circuit is operable to produce an identification signal in Morse code, the dot signs having a duration of about 200 ms and the dash signs a duration of about 700 ms.
6. Equipment according to claim 4 wherein the electronic circuit is operable to produce a signal at two frequencies f_1 and f_2 differing from each other by several tens of Hz up to 100 Hz,
- 10 the uneven signs in the succession of signs forming the signal being transmitted at the frequency f_1 , and the even signs forming the signal being transmitted at the frequency f_2 .
7. Equipment according to any one of the preceding claims wherein the emitter comprises a plurality of transducers, the electronic circuit being operable to supply the transducers at least two by two, so as to cover the horizon in several sectors.
- 15 8. Equipment according to any one of claims 1 to 6 wherein the emitter comprises four transducers arranged to form a square, the electronic circuit having switches adapted to connect the transducers two by two in opposite phase in two times four successive arrangements, each forming a sequence, so as to cover the horizon in two times four emission sectors, a complete signal code being emitted for each two by two arrangement, with intermediate pauses.
- 20 9. Equipment according to any one of the preceding claims wherein the emitter is mounted in a water-tight case in the bottom of the vessel above a window formed in the hull, the transducers being positioned vertically with their emission diaphragms substantially in the plane of the opening in the hull.
10. Equipment according to any one of the preceding claims wherein the electronic circuit
- 25 controlling the emitter comprises an impulse generator functioning as a timer and connected to a sequencer controlling the sequence of operations terminating in the formation of the coded signal, said sequencer itself being connected with the emitter via an encoder producing at least one signal-emission frequency, and through an amplifier, the generator being connected to a controller for enabling the desired emission parameters to be selected.
- 30 11. Equipment according to claim 10 wherein the encoder is connected to the amplifier through a signal conditioner which converts the square wave signal produced by the encoder into a sinusoidal signal, and wherein the circuit further comprises switching relays for the transducers arranged between the amplifier and the emitter, the relays being controlled, by way of an interface unit, by the sequencer connected directly to the controller.
- 35 12. Electro-acoustic equipment for the underwater detection and identification of a vessel, substantially as hereinbefore described with reference to the accompanying drawings.