TRIALS WITH ULTRA-SONIC ACTIVE RESPONDERS FOR LOCATING SEA-BED MARKERS AND LOCALIZING SURFACE VESSELS OR TOWED OBJECTS

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I. — INTRODUCTION

Whilst undertaking research and underwater work the "Société d'Etudes pour la valorisation des gaz naturels du Sahara" (SEGANS) was confronted in 1962 with the necessity to develop equipment for accurately locating structures planted on the seabed in a manner that would be both simple and economic. And this without being constrained to plant, for the case of work of a limited nature and short duration, costly radio positioning equipment, whose setting up necessitates much preliminary notice being given.

The "Compagnie Générale Doris" later took over from SEGANS.

On 1 January 1966 the "Bureau de Recherches de Pétrole" became ERAP (ELF), but already in 1964 it had, in its research programme carried out by the "Comité d'Etudes Marines", entrusted the SEGANS with additional work along the same lines, but with the emphasis on problems relating to oil.

Trials and developments for providing a solution to this problem started in June 1962 with the help in the first place of the "Société Alsacienne de Constructions Mécaniques", and since 1963 of this society's new subsidiary, Alcatel.

The principle selected was the measurement of the distance from vessel to object, using as marker an acoustic beacon which acts as a receiver/transmitter when interrogated by the surface ship. The interrogating frequency was so chosen that the beacon could be used with a standard navigational echo-sounder. The response frequency was such that it remained close to the resonance frequency of the interrogating echo-sounder, but it had to be able to deviate somewhat within the band-pass in order to allow several beacons responding simultaneously to the same interrogation to use various frequencies, thus facilitating their identification. Furthermore, the echo-sounder should not have to undergo any basic modifications which would hinder its navigational use.

Trials with prototypes and the development of advance models were carried out in tanks, at sea, and in the laboratory, between January 1962 and January 1968, by which date they were available commercially. During this period various improvements to the original prototype were carried out in order to take into account the performances obtained as well as the new possibilities revealed during these trials, such as the use of beacons for :

- navigational marks;
- high sea topographic datum;
- positioning of a towed object;
- positioning of a surface vessel within a beaconed zone.

We express our thanks to ERAP, SEGANS, the "Compagnie Générale Doris" and the "Société Alcatel" for permission to publish the results given here, and for having kindly loaned us the necessary documentation.

II. — REVIEW OF THE GENERAL PRINCIPLES OF SPECIALLY DEVELOPED RESPONDING BEACONS

The beacons are compact receiver-transmitter units for both sonic and ultrasonic waves, weighing 5 kg, with an endurance of from 1 - 2 years, and submersible to 1 500 m.

They include :

- an omnidirectional transducer for both reception and transmission which receives interrogations and transmits responses;
- a receiving stage which processes the received signal, works out and transmits the control signal for the response to the transmitting stage;
- a transmitting stage which receives signals from the receiving stage and works out the response signal which is transmitted to the omnidirectional transducer;
- a box for the incorporated electronics;
- a waterproof dry battery (or several);
- waterproof connectors for coupling the electronics to the batteries and the transducer.

The principles of operation are the following. An onboard transmitter (usually a standard navigational echo-sounder) transmits on its own frequency the same cycle of pulses as it does for its usual work programme. These pulses are received by the beacon base which in return transmits similar pulses on the same frequency, or on one that is sufficiently close, or else on an entirely different frequency.

These pulses are received on board the ship by the sounder's transducer, pass through the receiving circuits and then an adapter which changes the frequency and thus recentres the received signals in the receiver band. Any more conveniently adapted device (transducer and receiver) can be substituted for the sounder to give better directivity.

Whichever receiving device is used on board, the recorder registers on one and the same roll the distances :

— transmitting base to beacon base;
— transmitting base to bottom.

Simple relations from figure 1 have been deduced between the horizontal distances D_h, the oblique distances D_0 and angles θ.

$$D_h = \frac{p \sin \theta}{\sqrt{1 - \sin^2 \theta}} \text{ where } D_h = D_0 \sin \theta \tag{1}$$

$$D_0 = \sqrt{D_h^2 + p^2} \tag{2}$$

This infers that the acoustic paths sounder-beacon-sounder are direct and rectilinear.

D_{0t} is a computed theoretic value for the maximum aperture of the principal radiation lobe at depth p;
D_{0c} is the value read direct from the record;
D_{ht} and D_{hc} are computed from relations (1) and (2).

The geometry of both the principal radiation lobe and the first lobe of the secondary radiation in the EDO ANUQN 1C sounder in the vicinity of the transducer are roughly outlined in figure 1.

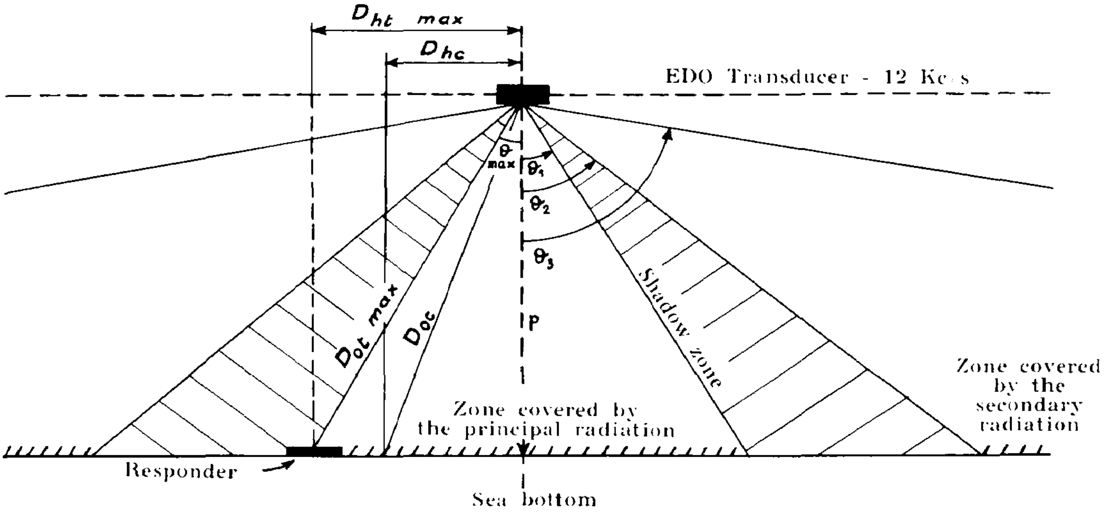

FIG. 1

The sonic level of this transducer is close to 112 dB, referred to 1 barye at a point 1 m from the transducer. The transmission loss at the frequencies used, and for oblique distances of several hundred metres (corresponding to depths of 0-500 m) is low, low enough for operating even outside the principal lobe. The "dead" zones — these are the minima on the directional diagram — are scarcely perceptible and amount to no more than a few degrees.

For any point a certain distance from the transducer, angles θ_1, θ_2 and θ_3 may be considered as respectively close to 30°, 50° and 80°.

For the EDO ANUQN 1C echo-sounder, taking $\theta_1 = 30°$, we have :

$$D_{0t} \max = 1.156\, p$$

$$D_{ht} \max = 0.578\, p$$

$$D_{0t} \max = 2\, D_{ht} \max$$

III. — BACKGROUND AND SUMMARY OF THE TRIALS

1962 — Equipment trials

A first series of trials was undertaken off Cadiz in June 1962 during preliminary research work carried out with the *Amalthée* (*) (fig. 2), an oceanographic ship used in connection with the Hassi R'mel project for laying an underwater gas pipeline between Africa and Europe.

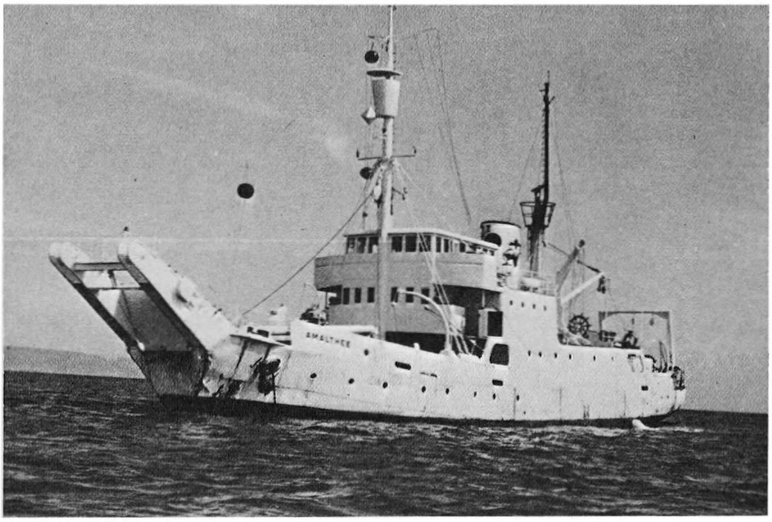

Fig. 2. — The oceanographic vessel *Amalthée*.

The interrogating EDO echo-sounder used a frequency of 12 kHz and the response frequency was 18 kHz.

A second series of trials was carried out in the same area in August of the same year, after modification of the echo-sounder's receiving stage, and using the transmitting stage of an Arcturus echo-sounder.

Tables 1 and 2 give values observed during the different runs.

(*) The *Amalthée* belonged at the time to ELF-ERAP, but has recently been acquired by the French Navy for its Hydrographic Service.

TABLE 1

28 and 30 June 1962

Run No.	P	D_{0t} max	D_{0c} max	D_{ht} max	D_{hc} max	θ max	Observations
1	86	99.40	90 m	49.70	27 m	$\theta = 17^\circ.5$	Start of settings
2	86	99.40	165 m	49.70	146 m	$\theta = 61^\circ.5$	Within a lobe of secondary radiation
3	86	99.40	275 m	49.70	250 m	$\theta = 65^\circ.5$	
4	340	393.04	485 m	196.52	360 m	$\theta = 46^\circ$	In the theoretical shadow zone

TABLE 2

Trial 2 on 2 and 3 August 1962

(1) EDO transmitter — EDO receiver — PDR

Date	No. of respndrs	Frequency	Depth	D_{0t} max	D_{0c} max	D_{ht} max	D_{hc} max	θ angle
2/8	2	18 kHz	32 m	37 m	332 m	18.5 m	330 m	83°
2/8	2	18 kHz	265 m	306 m	596 m	153 m	538 m	64°
3/8	2	18 kHz	540 m	624 m	1130 m	312 m	992 m	61°
3/8	3	18 kHz	200 m	231 m	535 m	116 m	496 m	67°

(2) Arcturus transmitter — EDO receiver — PDR

Date	No. of respndrs	Frequency	Depth	D_{0t} max	D_{0c} max	D_{ht} max	D_{hc} max	θ angle
2/8	2	18 kHz	32 m	32.2 m	282 m	3.9 m	280 m	83°
2/8	2	18 kHz	265 m	267 m	420 m	32.5 m	324 m	50°
3/8	2	18 kHz	540 m	544 m	550 m	66.3 m	104.5 m	$11^{\circ(*)}$
3/8	2	18 kHz	540 m	544 m	590 m	66.3 m	238 m	$24^{\circ(*)}$

(*) 13° difference between Θ angles for $D_{hc} = 104.5$ m and $D_{hc} = 238$ m. It is not here a question of maxima but of values observed during the two-minute recording of the Arcturus sounder.

Footnote : The theoretic values of the second part of the table were computed using the directional data from the Arcturus transmitter, although an EDO sounder was used for reception.

These two series of trials were of a purely technical nature and concerned the development of experimental prototypes.

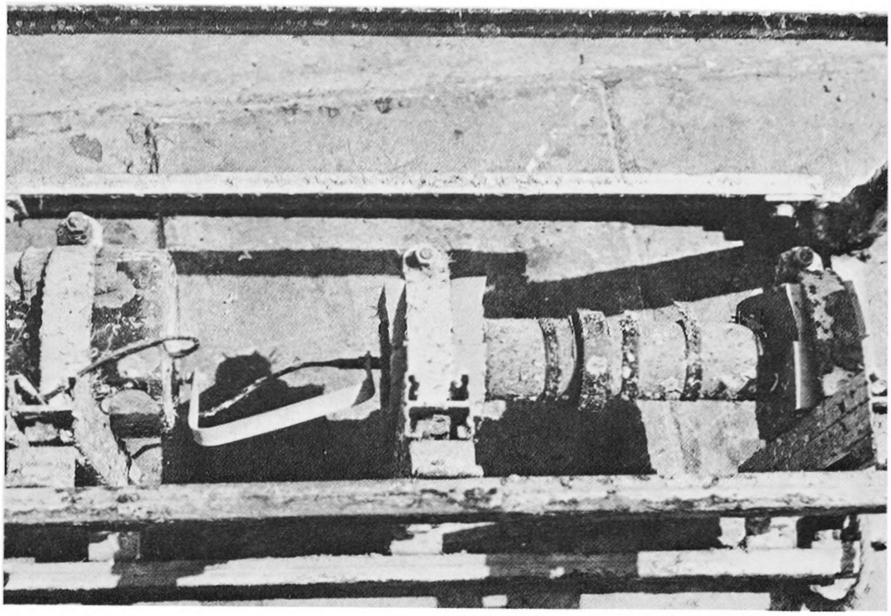

FIG. 3. — The first experimental prototype after a year's immersion.

The following conclusions have been drawn :

— the responders can easily function for angles θ which are larger than the maximum aperture of the principal lobes of interrogating sounders (7° for an Arcturus, 30° for the EDO);

— the bottom returns will have to be weakened in relation to the responder in order to avoid reading difficulties close to the vertical;

— the triggering threshold of the responder will have to be lowered in order to make the best use of the secondary lobe radiation, as well as to increase the effective range;

— it has now been established that a good use of responders will allow a ship to attain the vertical of a point somewhere inside a circle of about 500 m in radius.

1963 — Operational trials

The purpose of these trials was to ascertain to what degree the simultaneous reception of responses from two responders permits the positioning of a surface vessel moving within the area these responders cover, as well as to find the effective extent of this area, and if possible the accuracy of the movements measured. The trials were carried out in the Marseilles roads in 70 m depths on 8 November and 8 December 1963 using an EDO echo-sounder mounted on a barge. For the trials the barge was hauled on its anchors or else towed.

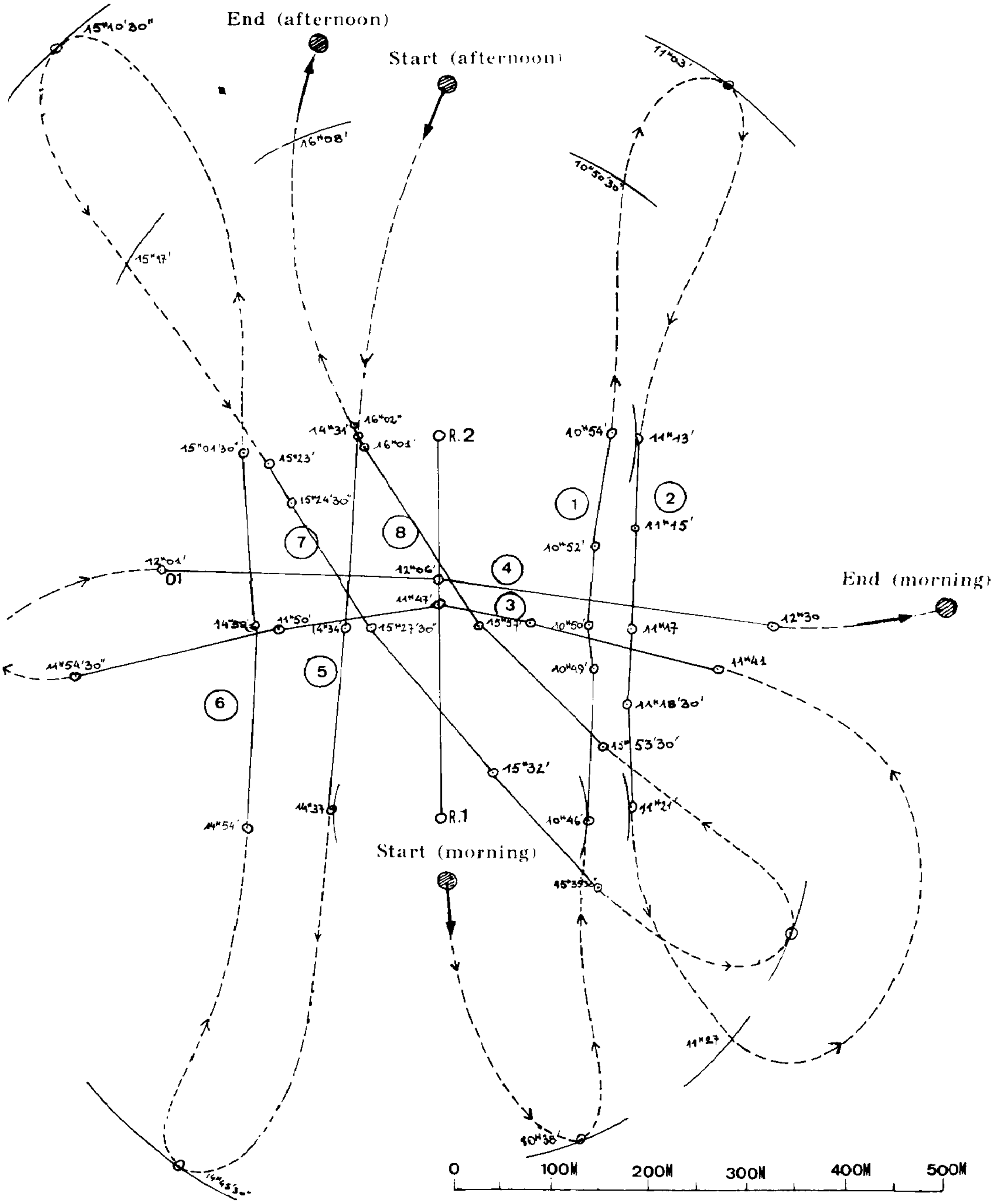

FIG. 4

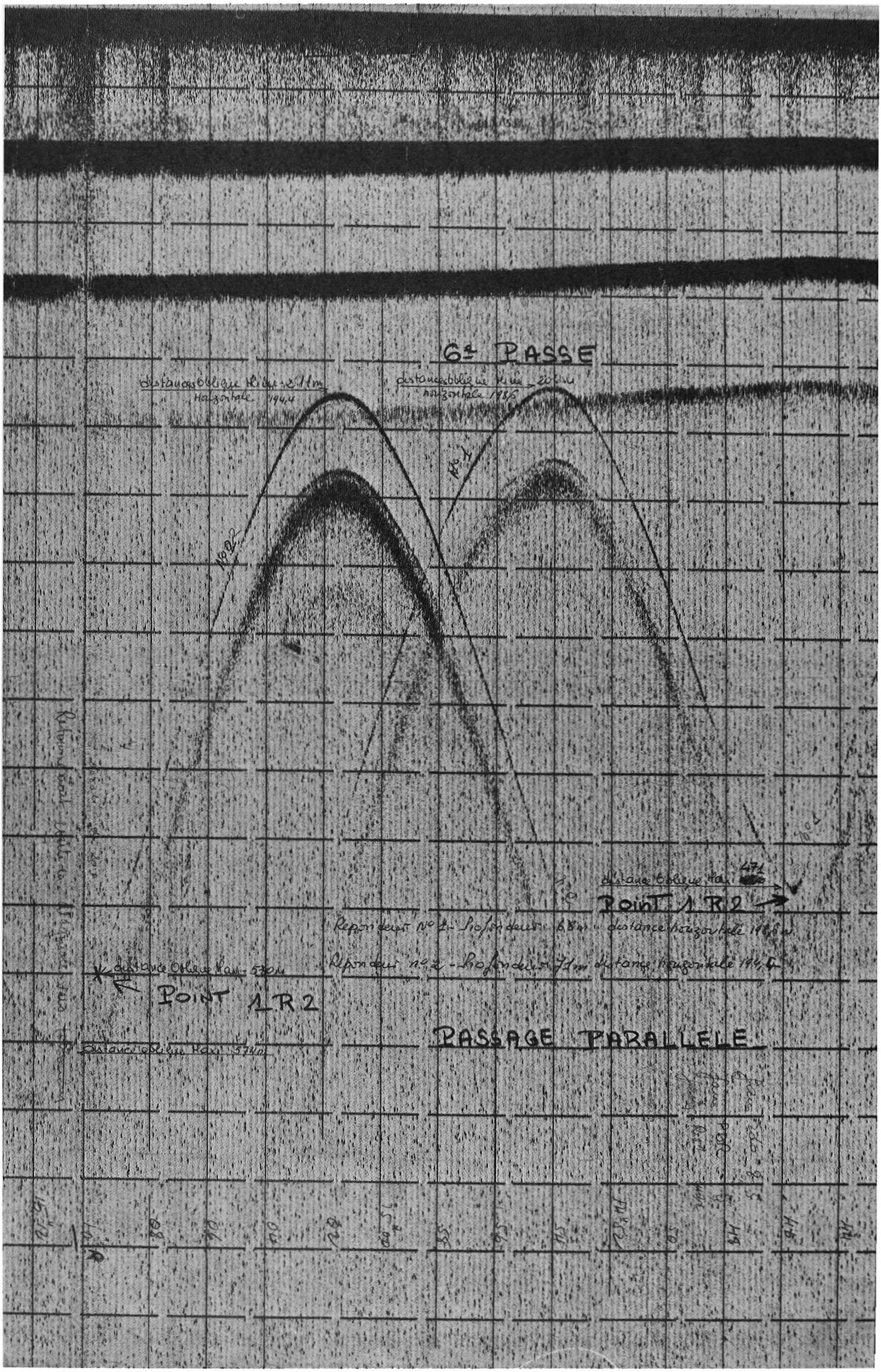

Fig. 5. — Record of the 6th run on 8 November 1963.

The responders used had the following characteristics :
interrogating frequency = 12 kHz (EDO) : 30 kHz (Arcturus)
transmitting frequency = 18 kHz.

The frequency changer (hereinafter called the adapter) was of the same kind as the one used for the earlier trials.

I. — *Localization of a ship underway: Effective area of operation* (8 November 1963).

The respective positions of responders and barge are shown in figure 4. Eight runs were made (numbered 1 - 8 on the figure), 4 parallel to the axis of the responders (2 on each side), two perpendicular and two oblique. This plot was obtained from the responder records, one of these being shown in figure 5.

Here the solid line shows the tracks run during reception from both responders simultaneously. Fixes on these tracks were obtained from two ranges. The dashed lines show the approximate tracks plotted from a single range and the data log.

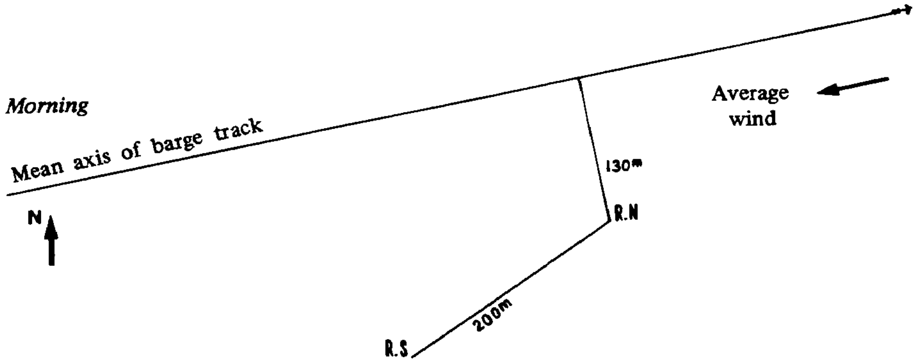

FIG. 6a

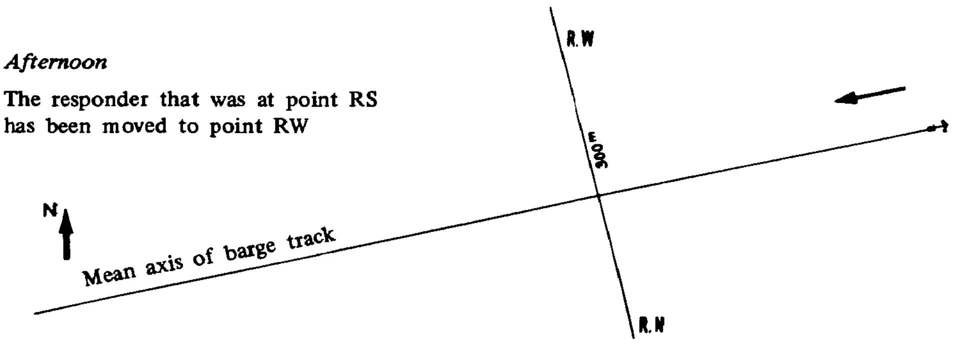

FIG. 6b

TABLE 3

Maximum theoretic and observed values for oblique and horizontal distances and for the θ angles during the No. 3 series of trials off Marseilles on 8 November 1963

Maximum theoretic values	R1	R2
Frequencies	18 kHz	18 kHz
Depth	68 m	71 m
D_{ot}	80 m	82 m
D_{ht}	40 m	41 m
θ max	30°	30°

Observed values for three of the runs

		R1	R2
Parallel run Point 1	D_{0c}	471 m	574 m
	D_{hc}	467 m	571 m
	θ	82°	85°
Perpendicular run Point 2	D_{0c}	412 m	461 m
	D_{hc}	407 m	457 m
	θ	80°	82°
Oblique run Point 3	D_{0c}	443 m	523 m
	D_{hc}	438 m	520 m
	θ	81°	83°

Footnote : Points 1, 2 and 3 are taken from the record, and are for maximum θ angles.

REMARKS AND CONCLUSIONS

The following remarks may be made.

1. The maximum θ angles for each responder are all close to 80°.
2. The nature of the echo trace (similar to a double echo) shown on each of these records is discussed in Section IV.
3. The size of the area within which an entering EDO ANUQN 1C equipped ship could position itself by means of two 1B type responders 410 m apart planted at a depth of 70 m is a rectangle of approximately 850 m by 1 200 m.

4. The signal/noise ratio was favoured by the fact that in this trial the transmitting face of the sounder installed on the barge was 1.90 m below the surface, and thus most of the vibrations and electrical or acoustical noises were excluded.

II. — *Measurement of the accuracy of short moves* (18 December 1963)

As the results of the trials of 8 November were fairly encouraging a whole day was devoted to attempting to measure the accuracy of the absolute values of these moves.

The two responders were marked by two surface buoys. The barge, held by anchors fore and aft, was hauled on its winches, and the moves were measured in terms of full turns of the winch.

Figures 6*a* and 6*b* show the respective positions of barge and responders.

The positions of the responders were observed by sextant at the time of planting. During the trial two surveyors positioned the barge's bridge in relation to geodetic marks, also by sextant.

For each move the following measurements were carried out simultaneously :

— length of chain let out or hauled in;

— angles between landmarks;

— oblique distances to each of the responders.

The lengths measured are shown in table 4.

REMARKS AND CONCLUSIONS

1. Although the clarity and the number of marks used was sufficient, the visibility was poor with the result that some of the moves could not be measured by sextant, and thus the accuracy of the plot is only of the order of 5 m.

2. The reliability of the PDR record and the homogeneity of the water in the 0-70 m layer in winter enabled us to consider the observed record values as both accurate and precise.

3. The agreement between the three methods of measurement for both the individual moves and the total length of the move demonstrates clearly the fidelity and accuracy of measurements with responders.

No. 4 series — the longest and also the one where the best conditions obtained for measuring angles and lengths of cable hauled in — led to the following remarkably satisfactory agreements.

— length of the move, measured with the responder . .	181.5 m
— length of cable hauled in	180.0 m
— distance between sextant fixes	175.5 m

TABLE 4

Lengths of moves

A calibration of length against number of full turns was made before these trials.

The barge's actual moves are usually longer than the cable length hauled in or paid out. This is due to sideways movement caused by the wind and the sea state.

Time	Cable paid out or hauled in	Move measured by responder	Move measured by sextant
111030 to 1120	Hauled in : abt. 68 m	63 m	Angles not measured
1125 to 1140	" 20 turns -64 m	63 m	70 m
1144 to 1150	" 10 " 32 m	25 m	Bad visibility, no measurement possible
1203 to 124215	Paid out : abt. 90 m	93 m	" "
143930 to 144415	Hauled in : 5 turns - 16 m	18 m	" "
144415 to 1450	" " 16 m	12.5 m	" "
1450 to 145730	" " 16 m	18 m	" "
145730 to 1505	" " 16 m	18 m	" "
1505 to 150720	" " 16 m	21.5 m	23.50 m
151230 to 151915	" " 16 m	18.5 m	Angles not measured
151915 to 152520	" " 16 m	16.5 m	17 m
152520 to 153105	" " 16 m	16 m	19.5 m
153105 to 153630	" " 16 m	21 m	Angles not measured
153630 to 1541	" " 16 m	19 m	14 m
1541 to 154630	" " 16 m	19 m	Angles not measured
154630 to 1550	" " 16 m	25 m	24 m
1550 to 1554	" " 16 m	20 m	19 m
1554 to 155850	" " 16 m	5.5 m	11 m
155850 to 160130	" " 16 m	16 m	18 m
160130 to 160645	" " 16 m	17 m	19.5 m
160645 to 160830	" " tripped	3.5 m	6 m

1964 — Development trials

The earlier trials had demonstrated :

- the accuracy of a responder positioning system and the extent of its effective range;
- the need for rejection of bottom echo;
- the need for a means of identifying each responder in a pattern;
- the need to increase the aperture of the active sectors of the onboard transducers at both reception and transmission.

The purpose of the 1964 trials was to put the improved equipment to test. These trials concerned :

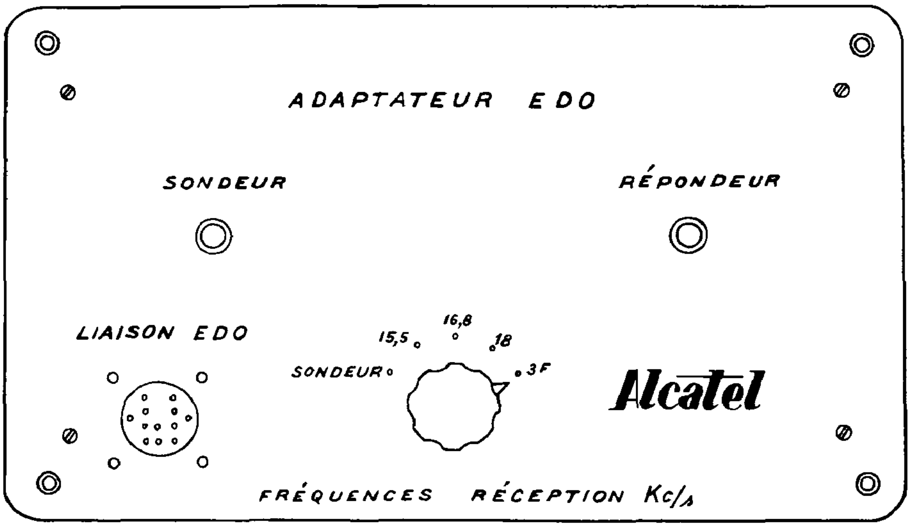

FIG. 7. — Front face of Alcatel-Doris adapter.

1. The simultaneous use of three technically improved responders of different frequency (15.5 Hz, 16.8 Hz and 18.0 Hz).

2. The use of a new adapter (figure 7) for :
— improving the attenuation of the bottom returns;
— receiving simultaneously from the 3 responders during the preliminary search;
— improving the signal from any one of the responders in relation to the other two, for purposes of identification.

3. The use of an omnidirectional hydrophone instead of the transducer. (The use of this hydrophone was limited to reception.)

The trials took place in Beaulieu Bay on 8 December 1964 in 80-m depths, using the experimental ship *Astragale*.

The responders were placed at the three vertices of a 285 m equilateral triangle and they were simultaneously interrogated on 12 kHz by the sounder.

The response signals were picked up by the hydrophone, were centred on a 19 kHz frequency and transmitted to the sounder's reception stage by means of an adapter.

The recorder was a PDR.

The operator could identify the echoes at will by means of a frequency selector built into the adapter.

The *Astragale*, equipped with a Voigt-Schneider propeller, maintained its position at the centre of the equilateral triangle which was marked by three surface buoys.

REMARKS AND CONCLUSIONS

1. The PDR record obtained during this trial shows the great improvement in the quality of the record, since the new adapter meets the aforementioned requirements.

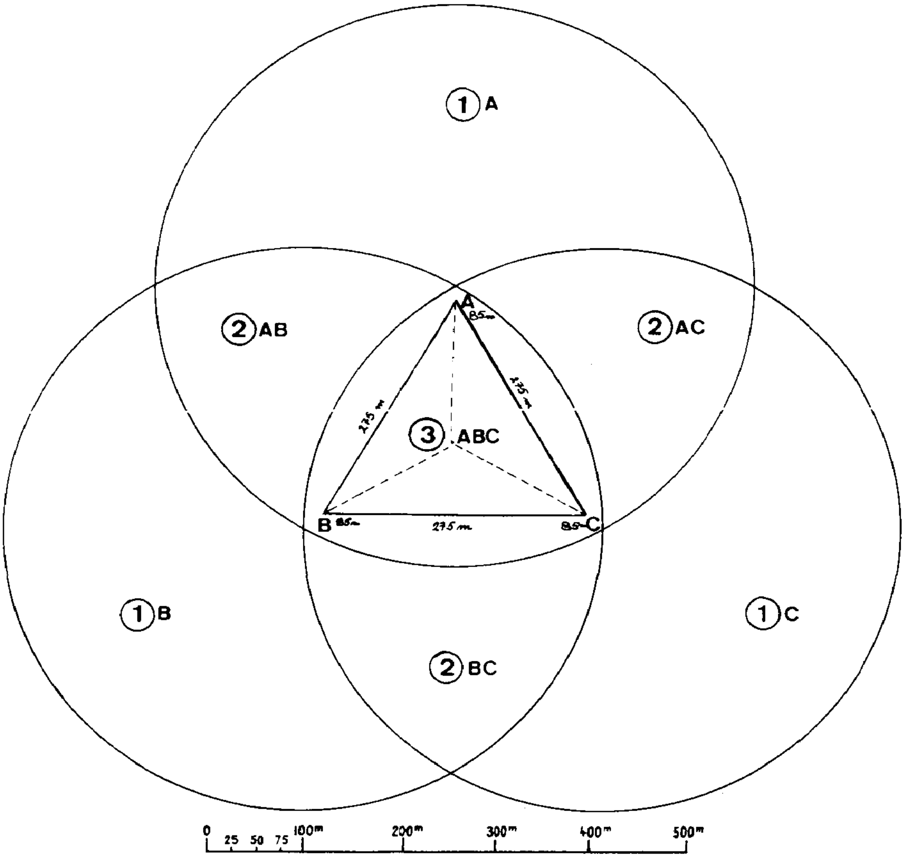

Fig. 8

2. *Figure 8 illustrates the possibilities of use of a pattern of* responders. These are that :

- a ship equipped for the purpose can usually gain without difficulty a region of the continental shelf in depths of about 100 m and marked by a pattern of three carefully planted responders because the effective range of this pattern is of the order of 1 km in diameter, and close to the coastline this is a value that is normally higher than positioning and dead-reckoning errors.
- once this area is gained the ship can at any time position itself in relation to the vertical of each responder with an accuracy close to a horizontal distance of 5 m (18 December 1962 trials).
- if the ship has improved means of manoeuvring it can remain on station on the vertical of a selected position at the time of the recordings.

3. The direct interpretation of the record by the helmsman is the best solution for manoeuvring in relation to a set of responders. This is especially so if the vessel has bow thrusters.

This particular trial could not be carried out for lack of such bow thrusters.

4. For remaining strictly on station visualization by graphic record is probably not the best means to place at the helmsman's disposal. In 1964 and 1965 the "Compagnie Génèrale Doris" carried out trials of visualization of responses on cathode ray tubes. These trials reached an advanced stage and were promising, but had to be broken off for want of funds. Figure 8 was drawn up by tracing circles of 300 m radius — the range generally obtained during the 8/9 December trials — these circles being centred on points A, B, and C where responders R_1, R_2 and R_3 were placed.

IV. — CONJECTURES AND ARGUMENTS

Directivity and sensitivity

Tables 1 to 4 show that most of the maxima for the observed θ angles are larger than the aperture of the EDO sounder's radiation lobe. Therefore we must assume that these operations profited from the lobes of secondary radiation.

The simultaneous use of the echo-sounder's directional transducer for transmission and an omnidirectional hydrophone for reception made it possible to establish that the responder sensitivity was sufficiently good to assure a response at sound levels 30 dB lower than the axis level (82 dB) for the same depth. When designing the equipment this sensitivity was purposely limited to avoid accidental triggering by unwanted noises, such as those from the bottom, waves, or marine life, or else from passing ships, as this would have had the effect of :

- shortening the life of the responders;
- preventing any measurement when passing close to responders (in shallow waters).

Considerable improvements to both the range and the signal/noise ratio have since been obtained by :

- using a more omnidirectional transducer with a resonance frequency of 12 kHz, enabling the use of an EDO sounder for both transmission and reception;
- increasing the acoustic power retransmitted by the responders, their transmission level being increased to over 75 dB. This only entailed a small increase in their size, and the decrease in their endurance was very small.

Multiple reflections

Unwanted traces can be noted on several records, and processing revealed that these were the result of acoustic paths with either one or multiple reflections. In fact, during the lowering of a responder to the bottom we could discern the trace corresponding to a multiple path :

— for the outward path : ship — responder;

— for the return path : responder — bottom — ship, or else responder — surface — bottom — ship.

The *difference in distance between the multiple* trace and the direct trace makes measurement of the distance responder to bottom possible. The arrival time at the bottom can thus be forecast and very accurately measured.

In every case of interference traces the normal trace always appeared simultaneously — except for short interruptions due to gaps in the sounder's directivity — and could in consequence be continuously followed, thus preventing any error of interpretation. Moreover, the signals reflected either once or several times generally show a characteristic attenuation due to dispersion of the rays as well as to the many reflectors (uneven bottom or sea surface).

The aspect of traces recorded from a vessel travelling on a uniform rectilinear route

(a) *Direct path (transducer — responder — transducer)*

The oblique direct distance is given by the formulae :

$$l_1 = \sqrt{d_0^2 + v^2t^2} \quad \text{and} \quad l_1 = \sqrt{d_h^2 + p^2}$$

taken direct from figure 9.

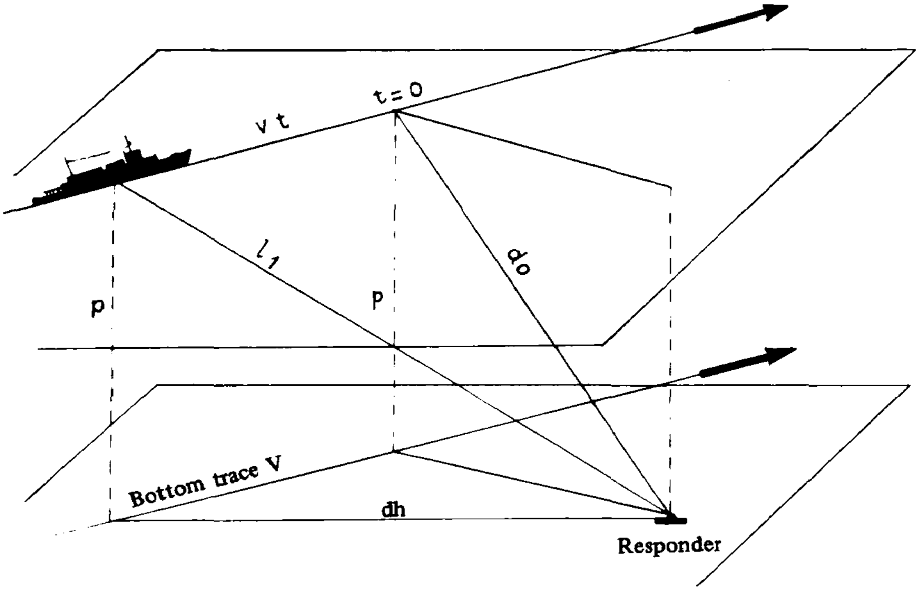

FIG. 9

The total acoustic path L_1 is equal to $2l_1$. Thus $L_1 = f(t)$ is a parabola with a minimum for $t = 0$.

(b) *Reflected outward path — direct return path*

Figure 10 is of the vertical plane passing through both transducer and responder. It is for the assumption that the principal lobe acts on the responder after two reflections.

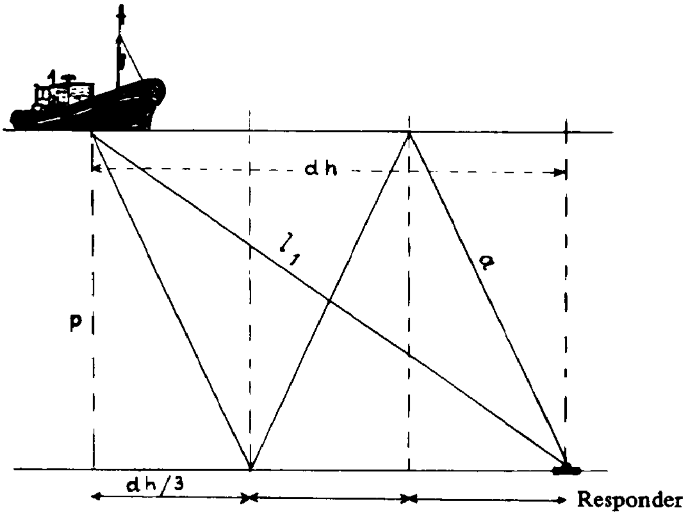

FIG. 10

If L_2 is the total acoustic path we have :

$$L_2 = 3a + l_1$$

with

$$a = \frac{1}{3}\sqrt{d_h^2 + 9p^2} \qquad \text{and} \qquad l_1 = \sqrt{d_h^2 + p^2}$$

whence

$$L_2 = \sqrt{d_h^2 + 9p^2} + \sqrt{d_h^2 + p^2}$$

$L_2 = f(t)$ obtained by expressing d_h as a function of t is also a parabola.

(c) *Comparison between the two paths*

If the value of d_h is expressed as a multiple of p, i.e. $d_h = p/n$ or $p = nd_h$, it results that

$$L_1 = 2d_h\sqrt{1 + n^2}$$

$$L_2 = d_h\,(\sqrt{1 + 9n^2} + \sqrt{1 + n^2})$$

and

$$L_2 - L_1 = d_h\,(\sqrt{1 + 9n^2} - \sqrt{1 + n^2})$$

~~which is an expression independent of the position~~ of ~~the ship in relation~~ to ~~the responder~~.

It can be seen that when the distance between the responder and the vertical of the transducer tends to infinity, then :

$$\frac{d_h}{p} \longrightarrow \infty \qquad \frac{1}{n} \longrightarrow \infty \qquad n \longrightarrow 0 \qquad L_2 - L_1 \longrightarrow 0$$

When the distance between the responder and the vertical of the transducer tends to zero, then :

$$\frac{d_h}{p} \longrightarrow 0 \qquad \frac{1}{n} \longrightarrow 0 \qquad n \longrightarrow \infty$$

and $$L_2 - L_1 \longrightarrow 2n \times d_h$$

If d_h is replaced by $\frac{p}{n}$

$$L_2 - L_1 \longrightarrow 2p$$

(d) *Remarks*

Traces corresponding to the two paths are almost always simultaneously visible on the records. It can be noted that :

(a) When $t = 0$, each of the values corresponding to paths L_1 and L_2 pass through a minimum;

(b) When $d_h = 0$, this minimum is equal to :

2 p for paths L_1
4 $2p$ for paths L_2

Accuracy of horizontal distance measurements (with a single responder)

The horizontal distance d_h is easily deduced from the oblique distance.

$$d_h = \sqrt{d_0^2 - p_r^2}$$

where d_0 is the oblique distance and p_r the responder depth. d_0 is read directly on the record and p_r is measured either when lowering the responder or else when passing directly over it.

We have :

$$\Delta d_h = \frac{d_0 \times \Delta d_0 - p_r \times \Delta p_r}{d_h}$$

which are errors to within the second order.

At a given moment d_0, p_r and d_h are constants with finite values.

Δd_h therefore varies as $d_0 \times \Delta d_0 - p_r \times \Delta p_r$.

The errors in d_0 and p_r are largely instrumental errors which are proportional to the values measured. Δd_h therefore increases with the difference $p_r \times \Delta p_r - d_0 \times \Delta d_0$; i.e. when d_0 and p_r are large and θ is close to 90°.

The instrumental accuracy is therefore increased as the ship draws closer to the vertical of the responder.

The propagation errors have little effect by reason of the shortness of the tracks and the shallowness of the layer of water. This effect also decreases when the ship approaches the vertical.

There may also be a possibility of random errors, although we did not encounter any during our trials which were carried out in average operational conditions where an accuracy of the order of 2 m for depths of about 100 m was frequently noted.

Accuracy of positioning by two or three responders

Positioning by two responders yielded the excellent results of the Marseilles trials which enabled us to establish that the positioning was accurate to within about 2 - 3 metres.

We were not able to carry out a positioning by three responders during the Beaulieu trials as the distance between responders had not been measured with accuracy, but this method would add additional accuracy to the two responder positioning procedure as well as the greater reliability that a third position line provides.

V. — PRESENT-DAY COMMERCIAL EQUIPMENT

The general characteristics of responders on the market today are :

- interrogating frequency (received by the responder) : two pre-set frequencies on each responder, selected between 10 and 30 kHz, i.e. the normal echo sounder band;
- response frequency (transmitted by the responder) : each responder has a pre-set transmitting frequency in the 10 - 18 kHz range;
- transmission level : 75 dB, with a directional diagram very similar to the omnidirectional one;
- reception sensitivity : varies according to the mark, the acoustic triggering threshold being between + 3 and + 15 dB;
- length of transmissions : 2 ms, with a blocking of less than 1 second between transmissions;
- endurance when in store : 2 years;
- endurance immersed (when used as receiver only) : over 1 year;
- endurance in permanent interrogation (1 pulse per second) : about 3 months;

— weight in air : approximately 5 kg;
— weight in water : approximately 1 kg;
— maximum immersion : 500 m; (A version for use at 1 500 m is being developed, but is not yet commercially available).

Adapters have already been developed for most of the standard echo-sounders (EDO ANUQN 1, Arcturus, Deneb, Scam, Kelvin Hughes, etc.).

The above characteristics have been fixed in order to answer the requirements of certain users, but they may be modified : in particular, the interrogating frequencies may be chosen outside the indicated band. However, the response frequencies selected must still be close to the resonance frequency of the transducer.

CONCLUSIONS

At the present stage of development oceanographers and commercial underwater enterprises can put these responders to various uses.

They provide a reliable cheap and accurate means for :
— marking a position or a structure on the bottom;
— marking out a channel without need of surface buoys;
— gaining a distant but already beaconed area;
— enabling a ship to position itself within this area by reference to the responders.

The present visualization of response signals renders it possible to return to a beaconed area and to navigate within it, but it is probable — although as far as we know this particular use has never been tried — that visualization is but a poor means for maintaining a ship or a manœuvrable floating platform on station. Visualization trials using a cathode ray tube that provides a more quickly apprehended picture of vessel and responders have been begun, and we believe that these trials would be well worth pursuing.