USE OF PHOTOGRAPHS OF RADAR IMAGES AS AIDS TO NAVIGATION

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IHB Note. — Lieutenant-Commander D. LORENZO MARTIN ROCA was born in Madrid on 20 May 1919. He entered the Naval Military School on 1 July 1939, and was commissioned sub-lieutenant on 20 June 1943. He was promoted to lieutenant on 1 September 1946 and lieutenant-commander on 24 July 1951. In 1948 he attended a course for specialists in hydrography, and in 1949 and 1950 a course for hydrographic engineers. As specialist in hydrography he took part in various hydrographic surveys on the north coast of Morocco, at the consol station of Seville, and on the Rio de Oro coast in Spanish West Africa.

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For many years the navigator has been in the habit of using *views of coasts,* which figure on charts and in Sailing Directions (Pilots), and which hydrographic services supply to facilitate the identification of conspicuous objects along coasts; he can in fact determine his position by bearings of landmarks which are mentioned on these documents and which are necessarily marked on the charts. In order to obtain an exact position, it is absolutely necessary that these landmarks be identified without error.

Nowadays, with the general use of radar navigating instruments, views of coasts have been advantageously replaced by *photographs of radar images.*

Views of coasts are of no use during foggy weather as it is then impossible to use the coastal landmarks to determine the position of the ship. On the other hand, radar photographs can be used, even during foggy weather, if the necessary precautions under these navigation conditions are taken according to the characteristics of the region.

The radar image supplied by the Decca-45 apparatus used by ships which cooperate with the Hydrographic Institute of the Spanish Navy for the preparation of Special Publication No. 7 — Collection of Radar Photographs, for Ferrol del Caudillo, Cadiz and Cartagena regions — suffic-

iently resembles the coastline traced on the charts to allow its identification. This identification can be extremely difficult, especially when the coast is low and flat and when one is trying to identify a landmark from a great distance, because the beaches become exposed very irregularly in places where their slope is very gradual.

SP No. 7 proposes to facilitate, thanks to the use of radar and its complement radar photographs, the identification of coastal landmarks at the time of landfall, the approach in certain cases to regions which are mentioned, and navigation in these areas when the sky is overcast.

The use of what are called *chart comparators* and the so-called navigation by *superposition* which depends on their use are not yet accurate enough when ordinary nautical charts are used, because of defects in these charts and the difficulty of exactly correlating the charts with radar images and radar charts. It is not exaggerating to say that the best radar chart is an exact copy of the radar photograph. Due to the difficulties already mentioned and the cost which is much lower than that of the *comparator*, it is much more interesting to use the *collections of radar photographs* to identify the coast by means of a radar navigation instrument.

The Hydrographic Institute of the Spanish Navy has begun to establish its collections by publishing in 1959 Special Publication No. 7 mentioned above which covers landfall regions and the approach to the ports of Ferrol del Caudillo, Cadiz and Cartagena.

Inasmuch as this special publication has been produced as a trial and owing to the diversity of sources of information used, our work is neither complete nor definite; and we hope that navigators will put forward some suggestion which will lead to improvements in this publication in their own interest, the aim of the Hydrographic Institute being to make navigation easier and more accurate for them.

In this article I shall take the region of Cadiz as an example, as a tribute to the Hydrographic Institute of the Spanish Navy to which I belong, as it is situated in that bay.

The brief plan for the preparation of the publication was the following :

a) The approach and coastal navigation routes most often used by ships coming from North Spain, the North Atlantic, the Canary Islands, the north-west coast of Africa, the Straits of Gibraltar and neighbouring coasts south-east of Cadiz were studied, i.e. all those most frequently followed to reach the bay of Cadiz.

b) A series of points on selected routes were chosen at different distances from Cadiz, whence the photographs of radar images were to be taken, in such a way that two adjacent photographs could not be confused one with the other (see fig. 1). According to the distances, the scales of the radar screen to be adopted were determined in each case.

c) The next step was to draw up practical instructions, (*a*) on the operating principles of the radar equipment when photographs were being taken, and (*b*) on the navigating with the ship used during the operations (the hydrographic ship *Tofiño*) which, in order to obtain the clearest and sharpest possible image, had to be navigated in such a way as to avoid sudden accelerations, rolling, etc.

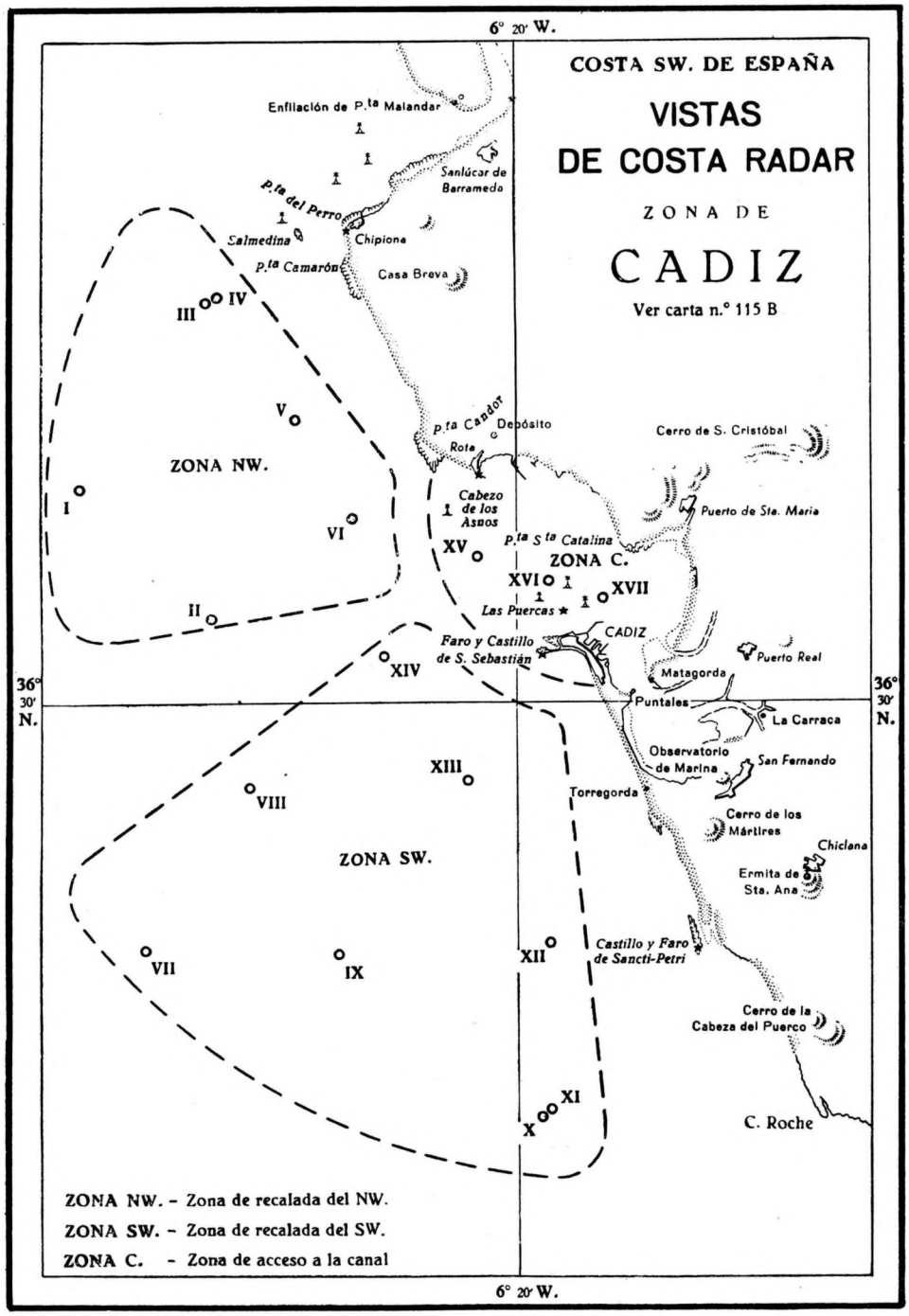

6° 20' W.
COSTA SW. DE ESPAÑA
VISTAS
DE COSTA RADAR
ZONA DE
CADIZ
Ver carta n.° 115 B
Enfilación de P.ta Malandar
Sanlúcar de Barrameda
P.ta del Perro
Salmedina
Chipiona
P.ta Camarón
Casa Breva
III
IV
V
ZONA NW.
I
VI
II
P.ta Candor
Depósito
Rota
Cabezo de los Asnos
XV
P.ta S ta Catalina
ZONA C.
XVI
XVII
Las Puercas
CADIZ
Faro y Castillo de S. Sebastián
XIV
Cerro de S. Cristóbal
Puerto de Sta. María
Puerto Real
Matagorda
Puntales
La Carraca
Observatorio de Marina
San Fernando
Torregorda
Cerro de los Mártires
Chiclana
Ermita de Sta. Ana
XIII
VIII
ZONA SW.
VII
IX
XII
Castillo y Faro de Sancti-Petri
Cerro de la Cabeza del Puerco
XI
X
C. Roche
36° 30' N.
ZONA NW. - Zona de recalada del NW.
ZONA SW. - Zona de recalada del SW.
ZONA C. - Zona de acceso a la canal
6° 20' W.

FIG. 1

d) In order to be able later to identify the points on the coast corresponding to the predominant echoes, the position of the ship was accurately determined on the chart by visual bearings on known points of the coast, whilst operating in good visibility. Then the bearings of the landmarks along the coast which supplied the predominant echoes were taken to facilitate their identification.

In order to avoid possible errors of identification, it is useful to note bearings and the distance of the fortuitous radar targets which may be visible from the sea, e.g. ships or other objects which are not permanently in the photographed panorama. It is also useful to note the position of buoys to enable their subsequent identification which is sometimes quite difficult owing to the weakness of their echoes.

e) With a view to being able to study the influence of the height of the tide, the time was noted when each radar photograph was taken, as the waterline can shift noticeably on very flat beaches. However, in our case, on the coast of the bay of Cadiz, the tidal amplitude did not exceed 1.90 m and its influence was very small, in spite of the presence of extremely flat beaches in certain places.

f) The ship chosen was supplied with a Rolleiflex camera with a Xenotar lens of 1:2.8/80, and an additional 32 cm lens; the camera was placed 50 cm from the screen of the radar receiver and was kept in place by a support fixed to the screen. The radar set used was Decca-45 with a 3 cm wavelength, its aerial being located 12 m above the waterline. In a set of this type the north of the picture appears permanently on the upper part of the screen to avoid the possibility of distorting the image when changing route.

g) From the photographic negatives, positives were obtained (see fig. 2) on which, once enlarged and correctly oriented in azimuth, the landmarks could be identified and numbered according to a key which was written at the bottom of each photograph. The necessary retouching was made on the positives to eliminate false echoes, as well as those of ships, and to eliminate photographic defects; and at the same time the echoes of important points were intensified if they had been weakened by abnormal circumstances.

h) These positives were surrounded, taking into account their orientation, by a large graduated rose from 0 to 360°, and served as originals to print the photo-etching plaques which were used for the printing of SP No. 7.

i) A radar photograph appears on each page, numbered according to its position on the index chart (see fig. 1), which is given before the three photographed regions.

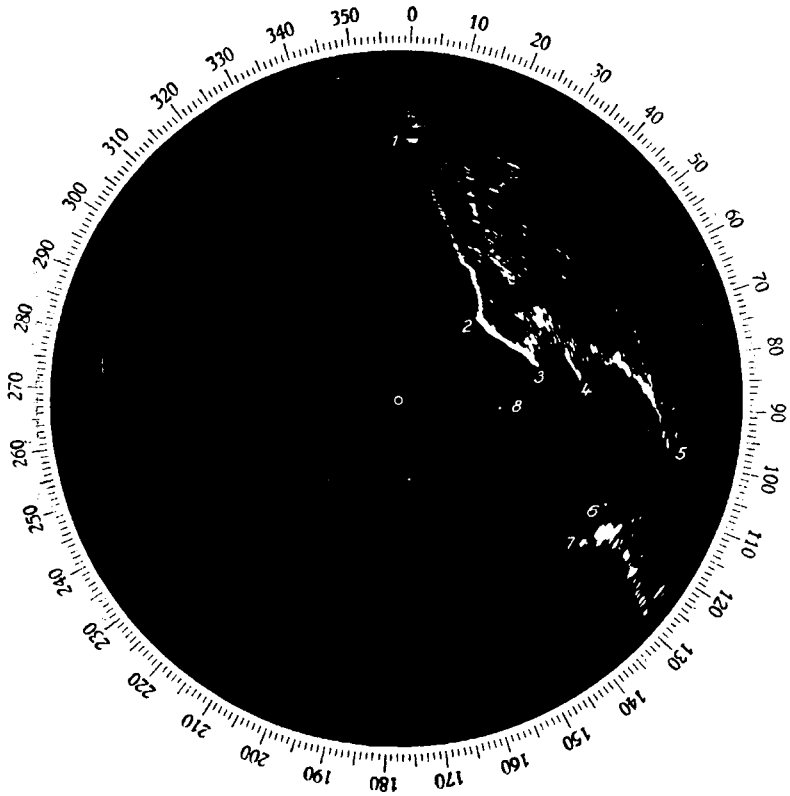
Above each photograph are written some interesting data, such as the height of the aerial, the scale of the radar screen used, the geographical name of the part of the coast, the indication of the region and the number of the photograph, to enable it to be identified.

At the bottom of each photograph is indicated the position from which the radar image was taken in relation to a landmark of the coast which

VISTAS DE COSTA RADAR — COSTA DE CADIZ

Escala de la pantalla: 10 millas
Altura de la antena: 12 metros

ZONA: "NW"
PUNTO: N.° VI



Vista n.° NW - VI

Situación: 7 millas al 305° del Faro de San Sebastián.

0.—Centro.
1.—Punta Camarón.
2.—Punta Candor.
3.—Faro de Rota.
4.—Rompeolas de la Base de Rota.
5.—Punta Santa Catalina.
6.—Las Puercas.
7.—Faro de San Sebastián.
8.—Boya del Cabezo de los Asnos.

FIG. 2

usually figures on the radar image. This position is represented on the photograph of the radar image by a small circle of which the centre coincides with that of the photograph.

At the bottom of each photograph are also written the key numbers which appear on the picture with an indication of the points to which they correspond.

j) Having tried numerous ways of marking on the photographs the position and the name of the landmarks, we gave up using a square grid method or a network of concentric circles indicating distance, as these systems reduced the clearness of the picture. On the other hand, the use of transparencies on which the identification numbers were marked presented difficulties in superimposing them exactly. That is why we were led to choose the system used which consists of writing, near the echo, a small figure in such a position and of such a size that it leaves the reproduction of the echo to which it refers as free as possible.

The use and the possibilities of radar photographs as aids to navigation naturally interest the navigator more than the way in which they are obtained, and that is why their rational use for navigational needs will now be briefly described.

For this study, it is useful to distinguish two completely different situations in which the navigator may find himself :

I) clear weather
II) foggy weather.

Under each of these atmospheric conditions, we must also consider two distinct kinds of navigation :

a) landfall navigation
b) coastal or interior navigation.

The navigator may thus be led to use the collection of radar photographs to help him make a landfall or to navigate along the coast. Each of these four cases will be examined.

Ia) *Landfall navigation during clear weather*
(See figures 3*a*, 3*b*, 3*c*).

When approaching the coast during clear weather, the navigator begins to receive on the radar set the first echoes coming from the most conspicuous points which are situated in the area of his landfall. These echoes give him a first approximate indication of the bearing and of the distance of the ship in relation to the landmark on the radar photograph and which one estimates would be the first to provide an echo at a great distance, although it cannot be seen with the naked eye because it is so far away.

These bearing and distance data will be corrected with more and more accuracy, as the echoes of other landmarks appear. When there are numerous landmarks in a coastal region which are detectable with radar, it is easy to fix them on the radar photograph and to deduce from them the points on the coast which correspond to the echoes, comparing the bearings and the distances read on the screen with those of the photograph; one then has data which, marked on the chart, give the position.

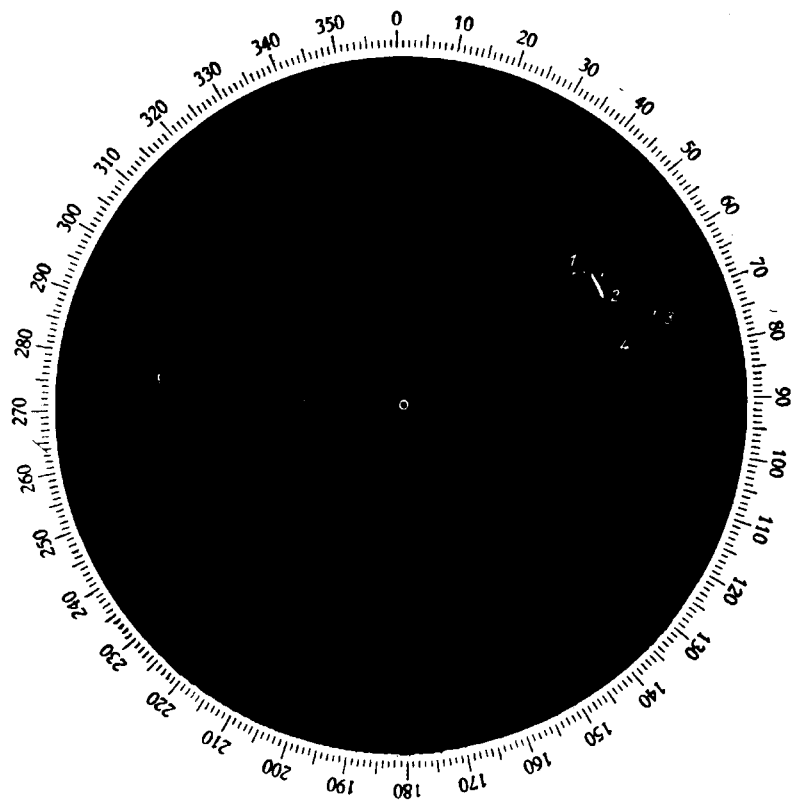
VISTAS DE COSTA RADAR — COSTA DE CADIZ

Escala de la pantalla: 25 millas

Altura de la antena: 12 metros

ZONA: "SW"

PUNTO: N.° VII



Vista n.° SW - VII

Situación: 15 millas al 234° del Faro de San Sebastián.

0.—Centro.
1.—Castillo de San Sebastián y Cádiz.
2.—Cortadura.
3.—San Carlos.
4.—Torregorda.

FIG. 3*a*

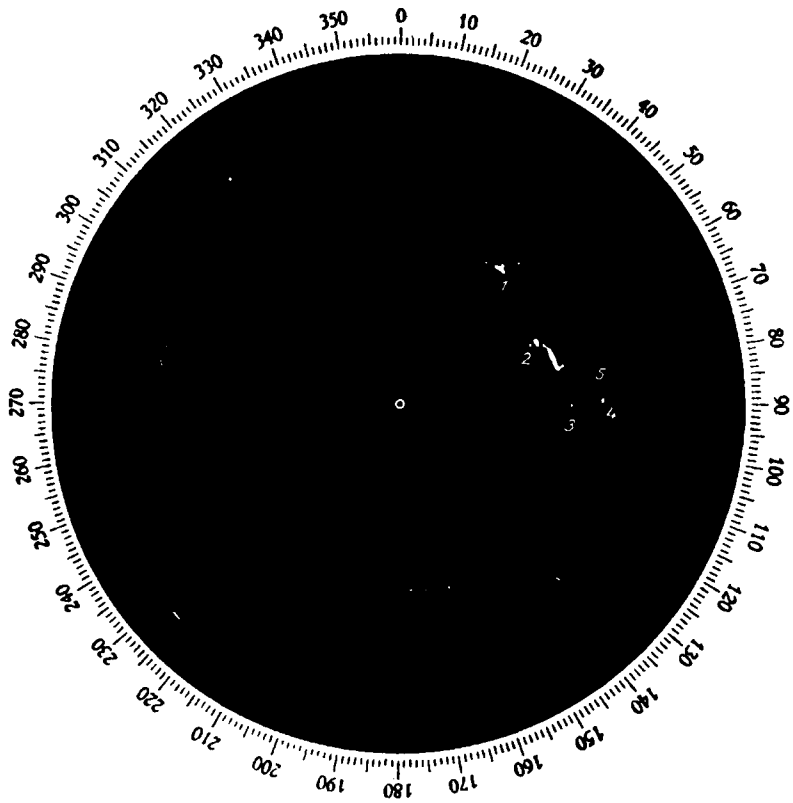
VISTAS DE COSTA RADAR — COSTA DE CADIZ

Escala de la pantalla: 25 millas

Altura de la antena: 12 metros

ZONA: "SW"

PUNTO: N.° VIII



Vista n.° SW - VIII

Situación: 10 millas al 245° del Faro de San Sebastián.

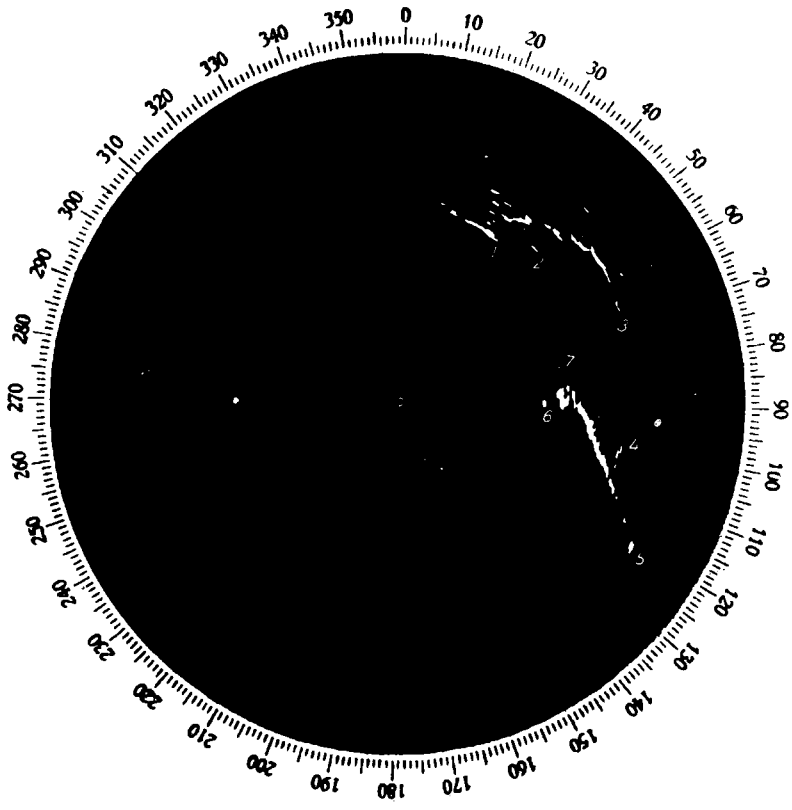
0.—Centro.
1.—Faro de Rota.
2.—Castillo y Faro de San Sebastián.
3.—Torregorda.
4.—Observatorio de Marina.
5.—San Carlos.

FIG. 3*b*

VISTAS DE COSTA RADAR COSTA DE CADIZ

Escala de la pantalla: 10 millas
Altura de la ántena: 12 metros

ZONA: "SW"
PUNTO: N.° XIV



Vista n.° SW - XIV

Situación: 4,3 millas al 268° del Faro de San Sebastián.

0.—Centro.
1.—Faro de Rota.
2.—Rompeolas de la Base de Rota.
3.—Punta de Santa Catalina.
4.—Puntales.
5.—Torregorda.
6.—Faro de San Sebastián.
7.—Las Puercas.

FIG. 3c

The nearer the ship approaches the coast, the more the echoes on the screen can be identified with the points on the chart which become visible to the naked eye, until it is possible to identify the landmarks of the coast perfectly.

Ib) *Coastal or interior navigation during clear weather*
(See figures 4*a*, 4*b*, 4*c*).

If one possesses photographs of radar images taken from a certain number of points near the coast or situated on a river, in a bay or a channel etc., it would then be easy to identify, in comparison with the radar images and the radar photographs, the landmarks which appear on the photographs with those which appear on the image and which are marked on the chart, and consequently also with those which are visible on the shore, which simplifies the determination of the ship's position.

For the particular case of navigation in rivers, channels, straits, etc., it is very interesting to use a series of photographs of radar images, since they will be a great help to the navigator who would be able to study them very closely when navigating during clear weather. The existence of buoys with radar reflectors, racons, ramarks and radar alignments, which are marked on these photographs, will help the navigator still more in his work.

IIa) *Landfall navigation during foggy weather*

During foggy weather, when the navigator is deprived of one of his principle faculties, *maritime visibility*, it will be very helpful to him to compare the information which he can obtain from his radar screen with the information marked on the chart. But, as the radar picture cannot be directly compared with the nautical chart owing to the fundamental modifications which it undergoes in practice as a function of the angle of incidence of the radar beam in relation to the coast, it will be necessary and very useful for the navigator to use the most complete series of photographs possible, perfectly differentiated one from the other, in order to be able to compare with them their radar images and determine the one which resembles them most; thus he will approximately determine the ship's position in relation to the points on the coast which show up best on the radar.

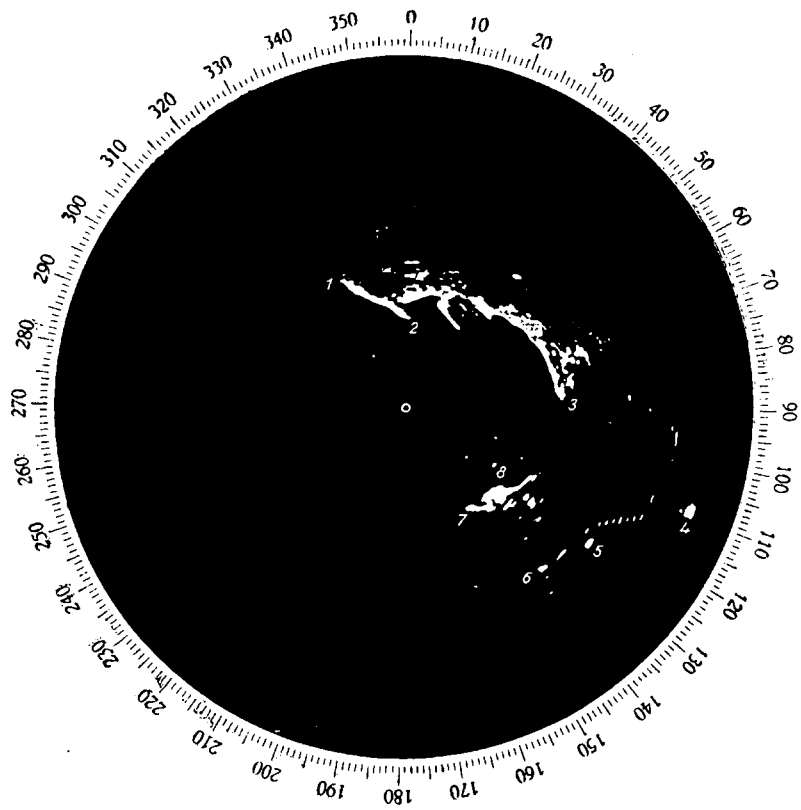
If this coast shows geographical irregularities or landmarks which provide notable echoes on the radar screen, the navigator will be able to obtain one or several reliable bearings which will enable him to approach the landfall region in safety, after having compared his radio image with the radar photographs of his collection.

I stress once more the fact that radar photographs do not precisely or definitely resolve the problem of making a landfall during fog, but they merely supply a supplementary aid to the navigator who cannot assure the safety of his ship by counting only on the interpretation of a few photographs. He will use this as supplementary information, and it will be of greater or lesser use to him according to the particular circumstances in each case and at each moment. The simple fact that the radar photo-

VISTAS DE COSTA RADAR — COSTA DE CADIZ

Escala de la pantalla: 10 millas
Altura de la antena: 12 metros

ZONA: "C"
PUNTO: N.° XV



Vista n.° C - XV

Situación: 3,5 millas al 325° del Faro de San Sebastián.

0.—Centro.
1.—Punta Candor.
2.—Faro de Rota.
3.—Punta Santa Catalina.
4.—Puerto Real.
5.—Matagorda.
6.—Balneario.
7.—Faro de San Sebastián.
8.—Las Puercas.

FIG. 4*a*

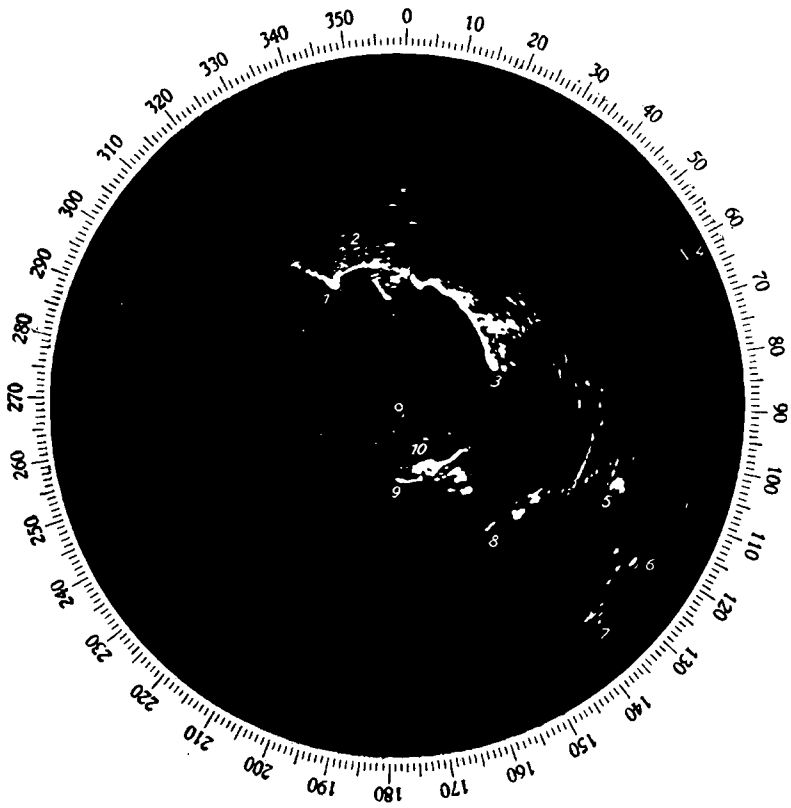
VISTAS DE COSTA RADAR — COSTA DE CADIZ

Escala de la pantalla: 10 millas

Altura de la antena: 12 metros

ZONA: "C"

PUNTO: N.° XVI



Vista n.° C - XVI

Situación: 2,0 millas al 005° del Faro de San Sebastián.

0.—Centro.
1.—Faro de Rota.
2.—Depósito con Aerofaro.
3.—Punta Santa Catalina.
4.—Cerro de San Cristóbal.
5.—Puerto Real.
6.—La Carraca.
7.—San Fernando.
8.—Puntales.
9.—Faro de San Sebastián.
10.—Las Puercas.

FIG. 4*b*

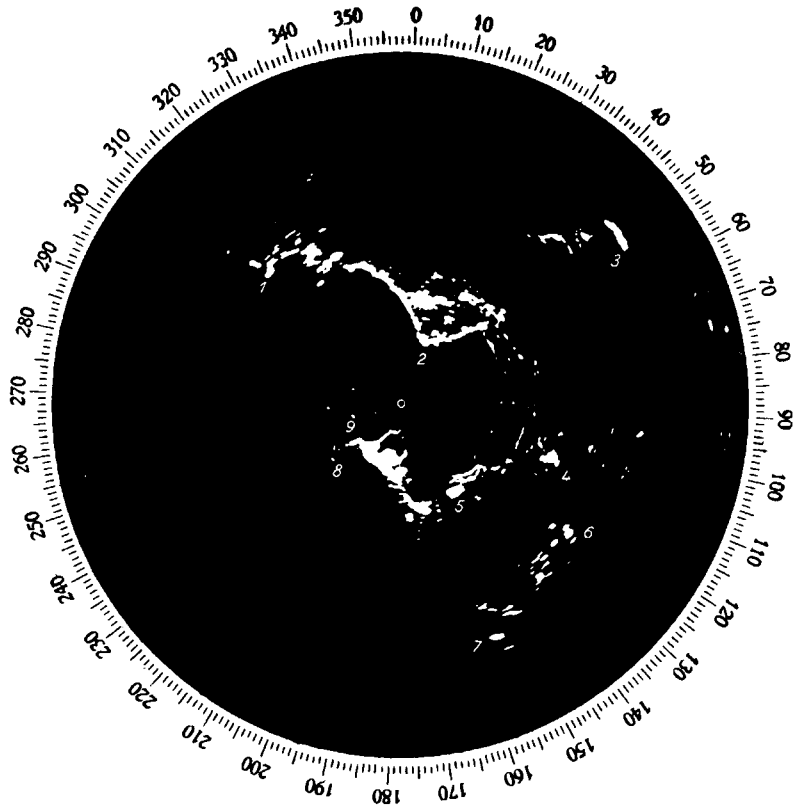
VISTAS DE COSTA RADAR — COSTA DE CADIZ

Escala de la pantalla: 10 millas

Altura de la antena: 12 metros

ZONA: "C"

PUNTO: N.° XVII



Vista n.° C - XVII

Situación: 2,3 millas al 050° del Faro de San Sebastián.

0.—Centro.
1.—Faro de Rota.
2.—Punta Santa Catalina.
3.—Cerro de San Cristóbal.
4.—Puerto Real.
5.—Matagorda.
6.—La Carraca.
7.—Cerro de los Mártires.
8.—Faro de San Sebastián.
9.—Las Puercas.

FIG. 4c

graphs can serve as aids to navigation is already enough to justify the existence of these collections in themselves.

II*b*) *Coastal or interior navigation during foggy weather*

If it is of interest to the navigator to be able to make a landfall during foggy weather, it is just as useful, if not more so, to be able to continue navigation during foggy weather with minimum acceptable security, approaching the coast and navigating in narrow waters.

In general, in confined areas, there are beacons or, on the coast, landmarks, which provide very definite and characteristic echoes, like precipitous points, buoys, beacons and isolated constructions, etc.; that is why it is relatively easy to follow a course according to the indications supplied by the radar image. If the navigator has radar photographs available, the correspondance between these points and their echoes will be facilitated. And, if the navigator takes the precaution of training himself during his navigation in fine weather while using his radar set and radar photographs, the latter could be of considerably more help to him.

Observations on the use of radar photographs

It is recommended to navigators who use radar photographs to take into account the following observations :

a) They should always remember that the echoes which appear first on the radar screen do not always correspond to the part of the coast which is nearest to the ship or which is highest, because these echoes are often provided by interior relief which is higher than the nearer regions, or inversely by lower steeper relief than the higher and more distant regions. Sometimes these echoes come from regions which show more normal surfaces to the axis of the radar beam, or which are covered with buildings which strengthen the intensity of the echoes.

b) On the coasts where the littoral is very flat in places, and where the tide has considerable amplitude, the navigator would take into account the state of the tide, as the distance between the ship and the coastline which produces the echoes can vary according to the irregular way in which the sea exposes the shore.

c) He should always identify more than three landmarks on the radar image with the radar photographs, to be absolutely certain not to make any mistakes.

d) He should always verify the scale of the radar screen to make it agree with the scale indicated on the photograph, and to avoid errors of identification and interpretation of the picture which could result from the use of a different scale.

e) He is advised, whenever possible, to trace *radar security lines* and to take them into account whilst navigating, when using radar photographs during fog.

f) He is also strongly recommended to trace the route followed at every moment during navigation with the aid of radar photographs.

Radar charts

It results directly from the study of the possibilities and the difficulties which the interpretation of the radar image presents, that it is with the help of radar photographs or the super-imposition of the radar image on the chart, that a problem occurs relative to the use of charts likely to make this comparison easy and safe.

The hydrographic services raised this question several times during the periodic meetings of the International Hydrographic Bureau at Monaco, without, up to the present, any practical solution being found. It is a question of deciding which is the type of chart which presents the most advantages and safety for the navigator using the aid of radar.

Some hydrographic services have decided to complete the topography of their charts by drawing contour lines and indicating their height, with the intention of giving the navigator an idea of the relief of the coastal region and its vicinity and thus to allow him to foresee, in a rather empirical way, the intensity of the echoes which he will receive off this coast.

As a variant to this solution, other hydrographic services, instead of contour lines, mark a rough sketch of the orographic irregularities, which facilitates the interpretation.

Others prefer to establish radar charts by intensifying the outline of the coast in the places where the strongest echoes occur; the accentuated outlines facilitate the identification of these coast positions, because the chart thus drawn more closely resembles the radar picture, and inversely.

Finally, a third solution exists, intermediary between those mentioned above: it consists of using the contour lines to indicate the profile of the relief and to publish at the same time some collections of radar photographs which facilitate the identification of the radar images with their representation on the chart. In this case the radar photograph is used practically, which facilitates the identification between the image and the chart.

Although this problem is still subject to lessons of experience, I think it would be of the greatest interest to all countries, through the intermediary of competent organizations in each case and particularly of the hydrographic services, with the intermediary of the International Hydrographic Bureau at Monaco and navigation institutes, to expose their personal points of view by making known the means used and the results obtained, with a view to trying to unite all attempts and to follow a firm and distinct doctrine on the subject of these problems which maritime navigation has had for a long time, without so far being able to find a correct and certain solution.