# RADIO DIRECTION FINDING CHARTS OVERPRINTED ON NAUTICAL CHARTS

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By setting up radio beacons and coastal radio stations and by improving radio direction finding systems within the last decades the development of radio techniques has been of great benefit to navigation for position fixing at sea. While in earlier years the navigator had to rely on a favourable visibility of visual reference marks (land marks, stars, etc.), there are nowadays electromagnetic waves to assist him in finding his ship's position at any time. With respect to the safety of navigation and of human lives at sea, radio direction finding systems have become an important factor. These developments had to be taken into account by the compiler of charts. The charts had to be provided with corresponding radio technical data in such a way as to enable the navigator to interpret the received radio signals readily and in as simple a way as possible for fixing the position.

In the following, brief comments are made on the principles of familiar radio direction finding systems, and later on their representation on nautical charts.

The oldest means of radio location is the radio direction finding of radio stations, the geographic location of which is known. The principle of determining the position in this way is the same as when fixing the position by means of visual reference marks. The visual beam is replaced by radio beams, which reach considerably further, and instead of the eyes and binoculars, electric receiving equipment is employed. The measurements under discussion are azimuth measurements as in the case of optical position finding.

In order to get the full value of radio direction finding for fixing the position of a ship, every radio station serving as a means of position fixing is indicated on nautical charts as follows (adopting the abbreviations used on charts) :

- RC : Circular radio beacon station;
- RD : Directional radio beacon station;
- RW : Rotating loop radio beacon station (Consol station);
- RG : Radio direction finding station (Gonio);
- R : QTG-radio station.

The exact positions of the radio stations are specified by a distinct dot (in German charts they are marked by a vertical cross within a small circle ⊕). In addition, on charts of some nations radio beacons are marked by a violet circle, so that they may be seen more clearly. On account of their great importance in position finding, on German charts circular radio beacons are emphasized with a vertical cross inside an orange-coloured circle (of about 7 mm). The outstanding part radio direction finding plays in position fixing is reflected by this clear marking.

Aviation radio beacons have for a long time not been included on nautical charts, since the geographical position as well as the frequency and time of transmission of these radio beacons were often changed. However, for some time now quite a reasonable stability has been experienced, and they have consequently been inserted on charts and were given the same signs as navigational radio stations. The addition of Aero (e.g. RC Aero) signifies that the beacon in question is for aviation.

To conclude, it may be mentioned that for certain sea areas there are radio direction finding charts on a gnomonic projection (great circles = straight lines) which facilitate the insertion of radio direction findings, especially bearings from at least two fixed bearing stations to the navigating craft.

We now turn to radio direction finding systems which call for special overprints.

The Consol system is a valuable aid in navigation, because of its simple application without any additional display aboard, because of its reliability and because its accuracy is sufficient for deep sea navigation. A Consol radio beacon (i.e. a rotating radio beacon within the medium wave range) transmits a lattice of locally fixed radio position lines; this lattice is connected to the transmitter and is subdivised into sectors. The location of the radio position lines is fixed by radio signs (dots or dashes).

For utilizing the received radio signals there are available Consol charts which contain the contours of the sectors (leading beam) in the form of an overprint and, according to the scale of the chart, further interpolation marks. As a basis for inserting the Consol beams, nautical charts are being used which are constantly corrected by means of Notices to Mariners, and thus are genuine navigational charts. Therefore, if the navigator wants to make use of his radio observations from the Consol transmitter for determining the lines of position, all he has to do is to trace his position line according to the number of radio signs (dots or dashes) heard between the leading beams and according to the interpolation marks printed on the chart. The point of intersection with another Consol position line will then supply the ship's position.

Between the printed beams the dot or dash sectors are characterized by dots or dashes inserted in the form of an arc of a circle around the transmitter. It is useful to choose the number of the dots or dashes between the drawn beams in such a way that they may at the same time serve as interpolation marks. Thus, for instance between two drawn lines of every fifth hyperbola four dots or two dashes with three spaces or three dashes with two spaces can be inserted.

The accuracy obtainable by means of Consol results from the subdivision of the sectors into 60 marks. It is highest near the main leading beam, whereas Consol becomes useless for determining the position near the baselines. The same applies within the range of approximately 25 nautical miles around the transmitter. Accordingly the main and interpolation beams of these ranges are omitted in charts, by means of which the navigator is adequately instructed about these special conditions.

While Consol was developed for relatively long range navigation (Consol charts mostly are of a smaller scale), the Decca system presents a method which gives exact position finding within a range of approximately 250 nautical miles from the transmitter. In the case of the Decca system, one takes advantage of the phase difference of simultaneously transmitted radio waves that occurs on account of varying paths to two separately erected transmitters. All positions of the same phase difference lie on hyperbolae, the transmitters being the focal points. Hyperbolae of a phase difference zero (called zero hyperbolae) border one lane, the phase difference in which may have any possible value. The geographical location of the lines of the same phase difference can be mathematically ascertained. Only zero hyperbolae are inserted on charts which enable the navigator to evaluate the measurement of the phase difference and thus find the ship's position.

In the case of Decca transmitting equipment (Decca chain) with one master and three slaves, there result 3 transmitter pairs and, accordingly, 3 differently situated hyperbolic patterns which produce a lattice of overlapping hyperbolae. In each chain the colours red, green, and purple are assigned to the decometer and to the representation of the hyperbolic patterns, whereby a reliable coordination is assured. For fixing the position one has to mark two decometer readings on the Decca chart and to interpolate between those zero hyperbolae marked accordingly. (Small diagrams are provided to ensure correct interpolation.) Since the transmitters are continuously operating, observations may be made at any time and do not depend on weather conditions nor on the time of day, etc.

The accuracy of fixing the position by means of Decca is, among other things, dependent on the distance to the transmitter pairs and on the angle by which the hyperbolae applied cuts the ship's position. In order to save the navigator form determining which chain is the best to use, the Decca charts mostly contain only the hyperbolae of the most suitable chain and frequently only the *two* hyperbolic patterns with the best angle of intersection. For the sake of clearness and legibility of the Decca chart one should only insert the third pattern of a chain if it gives a good control section for fixing the position; that is, if the third decometer reading and its insertion on the chart is of real advantage and offers additional safety to the navigator. Otherwise it is better to be satisfied with two hyperbolic patterns. This is particularly appropriate if the Decca chart serves as a direct navigational chart at the same time; this should be so as often as possible as it is simpler and safer. The transfer of a geographical position from a Decca chart on to the navigational chart is always troublesome and likely to cause errors.

Within a certain chart area the distance between zero hyperbolae of two hyperbolic patterns is only a function of the varying distances to the relevant transmitter pairs. Frequently, in order to cover a sea area with hyperbolic patterns of about the same distance, for instance only every third of one pattern and each of the zero hyperbolae of another pattern are inserted. This procedure creates considerable difficulty for the navigator, as such an arrangement calls for increased attention when interpolating. Besides this, the clear indication of the accuracy of the hyperbolic patterns on the chart is missing (because of the differing distance of the zero hyperbolae). It may be suggested, therefore, to keep the distance of counting the zero hyperbolae of various patterns in one chart as small as possible despite the fact that the linear distance of the hyperbolae of different patterns might thereby become unequal. The above mentioned disadvantages can thus be eliminated.

For some time now several authorities have been issuing Decca charts on which are printed hyperbolae of two neighbouring chains. These charts represent areas in which the hyperbolae of only one chain each intersect very inconveniently, but where the hyperbolae of two neighbouring chains have an almost rectangular intersection. When preparing such charts with hyperbolic patterns of two chains one has to proceed very carefully in order to keep the chart clear and easily legible. Otherwise it may easily resemble a paper pattern.

For such charts it may be wise first of all to examine which of the possible Decca chains of a certain area bears relatively the most favourable geometric and electromagnetic conditions. Of this chain two hyperbolic patterns are to be inserted. Of the second chain the illustration of only one hyperbolic pattern giving the best intersections with the patterns of the first chain ought to be sufficient. To make it clear that a second chain is dealt with, it is useful to define these hyperbolae by long dashes. By additional remarks in the chart margin special conditions may once more be pointed out. It is not advisable to choose another colour for the hyperbolae of the second chain, since the colours of the hyperbolae and of the decometer should in each case correspond.

The navigator is thereby provided with the possibility of making exact position determinations also in regions where the ship's position can only be determined relatively inaccurately by means of the Decca chain. Ships provided with only one decometer and which do not want to switch over their decometer between observations are able to determine their position in the usual manner by means of the hyperbolae of the best chain. The insertion of three hyperbolic patterns on the chart will not make it too congested.

In conclusion on the subject of Decca charts, I wish to refer to charts which contain the overprint of improved hyperbolae. The calculations for determining the positions of the hyperbolae are carried out by means of the mean velocity of propagation of electromagnetic waves. From locally abnormal conditions fixed errors might result; they can be determined by reference measurements. The position of the hyperbolae can thus be adjusted and Decca charts including corrected hyperbolae can be published. For instance, this was done by Sweden for different sea areas.

Loran provides the navigator with a navigational radio system for large distances. It measures the differences of the transit times of radio impulses that are transmitted simultaneously by two transmitters distant one from the other. All positions of equal time (path) differences lie on hyperbolae of which the geographical position can be estimated. Loran hyperbolic charts serve as a basis for the evaluation of Loran measurements, amongst others. The danger of confusion is largely excluded by the printing of the hyperbolae in colour and by distinctive numbering. The importance of Loran for long range navigation is likely to increase with the construction of new Loran transmitting systems.

The practical application of electromagnetic waves for marine navigation has called for the production of radio position finding charts. These charts serve their purpose as a navigational aid, especially if their publication is based on nautical charts. The navigator is thus able to insert directly on to his navigational chart the ship's position which he has obtained by radio observations. The importance of radio navigational charts is continously increasing because of the advantage radio navigation offers to determine at any time the position of a ship.