

## COMPARISON BETWEEN TWO DECCA CHAINS

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1. — In any investigation of the accuracy of Decca fixes it is necessary to distinguish between systematic and random errors. Investigations are generally based on a comparison between a Decca fix and a fix obtained by some other method; because of the high accuracy of Decca the other method must in practice be a terrestrial fix. The investigation can be made by comparing the decometer readings with values calculated for the true position; or the Decca position may be compared directly with the true position. The first way gives the differences of the Decca observations in terms of percentages of a lane, and the second shows immediately the errors of the Decca fix. The second method includes the uncertainty caused by the siting of the Decca stations, that is by the angle of intersection of the Decca hyperbolae. The second method will be of more direct use to practical navigators while on the first will be based considerations of a theoretical and strictly technical nature.

For the analysis the differences Decca observed minus Decca calculated or Decca fix minus true position are arranged in groups, the mean value of each group being the systematic error; the deviations from this mean value are the random errors. The absolute average error derived in this way gives the internal accuracy; the systematic error gives a measure of absolute reliability.

2. — If it is possible to observe two Decca chains, fixes from the two systems can be compared. The systematic errors may be determined in this manner more reliably, because there then exists an external standard of comparison. Even when there is no possibility of fixing by terrestrial observations, or any other means, the comparison of Decca fixes from two systems represents a way of investigating the errors. This method was first used (so far as the writer knows) by Cottle (1), who used two Decca chains to obtain accurate fixes at long ranges; these fixes differed by 5 to 6 miles! To obtain more accurate positions, Cottle constructed the bisectors of the angles formed between the lattice lines of each chain. Their intersection gave a better position, which differed, so far as could be established, from the true position by 0.2 to 0.3 n.m., whereas the positions by the single lattices were erroneous by several miles.

3. — In the North Sea Decca positions obtained by day are accurate to at least 1 n.m. Therefore the observations of Cottle must show systematic errors. The use of bisectors to obtain position lines free from systematic errors is familiar in nautical astronomy, where position lines are affected by the same systematic error, such as anomalous dip of the horizon (2). Cottle does not claim that cause but he says that the direction of the long axis of the ellipse of errors, which corresponds to the bisector of the angle, is determined by the distribution of random errors.

4. — There exist differences between the basic surveys of different countries, although each is internally consistent. There is, for example, a difference of + 6'' (180 m.) in latitude and — 9'' (150 m.) in longitude between the German and the Danish surveys, which must be taken into account in exact investigations. It is interesting to speculate whether such differences can be detected by a comparison of Decca fixes from separate chains.

This problem arises in surveying but also, in quite another manner, in navigation itself. For survey purposes the decometer readings are not used directly, but are corrected by observations from a monitor station; these corrections differ from day to day and take into account the systematic differences between the surveys. This only concerns the internal accuracy. In navigation the Decca values are used without correction or are corrected only by the so-called data sheets, which are constant for a given area. The position fix is an absolute one for the survey on which the particular charts are based.

5. — For recent (Nov., Dec. 1955) Decca fixes taken on board the ferry *Deutschland* (Grossenbrode-Gedser) to compare the accuracy of the German and the Danish chains (the former far away, the latter nearby) these differences had to be taken into account. Even though the track of the ferry-boat guaranteed an exactly known position, the position was often determined by horizontal sextant angles as well and this terrestrial fix was compared with the Decca position from both Danish and German chains.

The results for the Danish chain were very accurate because of the short distance from the stations of this chain. Two charts were used for the comparison of Decca and terrestrial fixes, one on 1:25,000 drawn for the purposes of the German surveying vessel, the other to scale 1:130,000 printed by the Danish authorities. The evaluation on the larger scale chart obviously gave a greater accuracy for the Decca fixes, especially when the terrestrial positions were calculated ( $\pm 0.063$  n.m.) and not merely plotted by station pointer ( $\pm 0.097$  n.m.). The accuracy assumed in the Danish chart is less ( $\pm 0.114$  n.m.). The systematic differences between the Decca fixes and the terrestrial positions derived from the two charts differed by exactly the above-mentioned values for the two surveys.

6. — The results for the German chain were not so good. The mean systematic differences between Decca and visual fixes (+ 0'.32 in latitude, + 0'.27 in longitude) when subtracted gave a mean error four times as great (+ 0.4 n.m.) for one position as the Danish chain fixes. This figure becomes even worse if the particular lane observed is taken into consideration. The positions on the well-buoyed channel are always so precise, even without using terrestrial fixes, that the readings of the vernier and the sector can be disregarded. These readings often varied from minute to minute, so that for navigation when entering the coverage of a Decca chain it will not always be possible to remove the ambiguity, especially at night. The comparison of fixes by two Decca chains shows not only the nearer system as four times more exact than the remote, but often as the only useful one.

7. — Nevertheless, the accuracy of the German system is better than that derived by Cottle in the North Sea for equivalent distances. In particular the systematic errors are smaller. This is shown also from observations made in the North Sea on the Pit-Way alternately with the German and the Danish chain, with the intention of finding the systematic difference between the two surveys.

Whereas the observations in the Baltic were taken at night and by day, those in the North Sea were made (in 1953) only under the best conditions in the hope that the simultaneous observations of two chains would be free from certain systematic errors influencing the two wave groups in the same manner. But in spite of all precautions the errors were too big to reveal the influence of the systematic errors of the surveys. Again, as in the other observations, the mean of all differences between the two Decca fixes, the German deduced on the basis of the German survey, the Danish on their own, was considered as systematic, the deviations from this mean being caused by random errors. There was a great enough scatter for the influence of differences in the surveys to be apparent. The quantity was the same as in the Baltic for the more distant system. The mean values were also great, but smaller than those derived by Cottle. Moreover the systematic differences alter, since a repetition of some observations in the summer of 1955 showed different values to 1953.

8. — These systematic differences must have causes other than the differences between surveys. It is likely that the velocity of electromagnetic waves is not constant but varies with time. This variation depends on the conductivity of the soil on the path of the waves, which varies itself with weather and climatic conditions. So far as it acts equally on all waves in one survey system, the use of the bisector as a position line, proposed by Cottle, suggests itself straight away. It also seems clear why the German chain should show smaller errors in the observations referred to than the two other chains described by Cottle. The administration of the German chain tries to make the hyperbolae conform with their position on the charts by shifting the phase from time to time to correspond to observations made in some monitor stations. It therefore seems possible to guarantee an accuracy of 1 n.m. for a Decca fix. But it does not seem possible to use Decca for the interesting possibility of comparing two survey systems.

9. — It will also be impossible to derive the velocity of propagation by comparing Decca fixes from two chains. Local and temporary influences are too numerous, so that the velocities depend on too many parameters. Nevertheless, it seems possible to estimate the variations of velocity for *one* chain by careful investigations from fixed stations over a long time. With this information it will be possible to obtain a better agreement between Decca fixes from two chains at long ranges. But there will always be a limit because any such comparison can only be made at a distance, at least from one of the chains, if not from both, where experience shows the accuracy is much reduced.

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#### REFERENCES

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