# INVESTIGATION ON ACCURACY OF THE DECCA NAVIGATOR SYSTEM.

## *AUGUST 1949 REPORT ON TRIALS IN THE NETHERLANDS.*

*(Received from the Netherlands Hydrographer).*

## Decca as an aid to land-surveying

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### INTRODUCTION.

Very extensive trials carried out by the Royal Navy, the Royal Netherlands Navy, the Br. Admiralty Signals & Radar Establishment, the Decca Co. and others, have shown that Decca is a valuable and accurate aid to navigation.

The trials have also proved that Decca is a very useful aid to Hydrographic Surveying (2 special survey Chains are in use for that purpose, a third one is about to be installed and others are under consideration) and for tracking of aircraft in aerial surveys. The number of trials for accurate position fixing in the air in aerial surveys is very limited.

The standard errors at sea in a reasonably well sited Survey Chain (the siting of the transmitters is not very critical in Decca) are of the order of 0.02 of a lane and it is not expected that they will be larger in free air. Extensive accurate position fixing trials in aerial surveying will be held in Holland in the fall of this year in order to get reliable figures.

There is however one application of Decca that was unsatisfactory until now. It is Decca-position-fixing on land. Trials made, showed that the Decca patterns were seriously distorted when the observations were taken in more or less heavily wooded terrain. One of those trials was made in the Netherlands and has been described in my report of January 1948. In this report the conclusion was made that Decca was not sufficiently accurate for land-surveying, not even for reconnaissance surveys.

This conclusion was disappointing, because it would have been of great practical and economic value if one and the same system could have been used for Hydrographic work, aerial surveying and reconnaissance survey on the ground (for instance geological reconnaissance) at the same time, because additional receivers do not add much to the total cost of purchasing a Decca Chain.

About 3 months ago however the Decca Co. succeeded in developing a new technique of interpretation of the normal Decca transmissions, making it possible to determine the amount of the local distortions of the Decca patterns when making observations in wooded terrain.

Although it is expected, it cannot be said with absolute certainty now, that all kinds of local distortions on the ground can be determined by this new technique.

For that purpose further trials will be held. The results of the trials to be described in § 2 of this report however show that the new technique is very promising and reduces the errors to an amount comparable with Decca observations taken at sea or in free air.

A full description of this new technique cannot be given here, but it is expected that the Decca Co. will publish the technical background in due course.

There have been no alterations at all in the transmitting equipment. The receiving equipment is a normal Decca receiver in which a slight modification has been made in the circuits of the purple decometer.

The three decometer-readings Red, Green and Purple are taken as usual and in addition the purple decometer gives a so-called " false purple " reading. This false purple reading gives the amount of the local distortion (caused by the objects surrounding the receiver) of all 3 patterns expressed in hundredths of a lane. The 3 decometer-readings R, G and P corrected

for the false purple reading give the correct Decca coordinates in a hyperbolic pattern computed with the usual formulae.

The weight of the equipment in its final—transportable—form is 83 lbs, including a 12 volt battery, and the whole is packed in 2 boxes of about 40 lbs each.

The reception of the signals is on an isolated whip-antenna, terminating in an earthing spike. The length of this antenna varies with the distance to the transmitters; 6 feet proved to be sufficient at about 100 kilometres and 20 feet at 320 kilometres.

Setting up the antenna and the receiver takes less than 1 minute. Taking the readings also takes less than 1 minute, but it is advisable to take the mean of several readings over a period of say 5 minutes.

## THE TRIALS.

**Trials and results in Great Britain, June 1949 (see fig. 1) :**

The trials were held in Epping Forest near London. 23 observations were taken ; all stations were part of a closed circuit traverse carried out by the Depart. of Engineering, University College; consequently the coordinates of the observation stations were accurately known.

Of the 23 observations made, all but two were in heavily wooded country under a practically continuous canopy of foliage ; height of trees between 60 and 100 feet.

The false purple readings—being the amount of the local distortion of the Decca patterns — varied from station to station, depending on the character of the overgrowth in the surroundings of the receiver; they were of the order of + 0.15 of a lane for the 21 stations under thick coverage and of the order of 0.02 for the two remaining stations where the terrain was practically open.

After correcting the normal decometer-readings for the false purple correction and comparing them with the "exact" Decca coordinates as derived from the terrestrial coordinates of the stations, the following standard (68 %) errors have been computed :

± 0.033 of a lane for Red.
± 0.033 — — Green.
± 0.028 — — Purple.

The aerial used was 6 1/4 feet long.

Approximate distances to the transmitters :

| | | |
|---|---|---|
| Master ..... | 20 | kilometres. |
| Red ..... | 130 | — |
| Green ..... | 80 | — |
| Purple ..... | 80 | — |

These results, using such a simple method and such a small aerial in heavily wooded terrain, looked very promising, taking into consideration that otherwise the errors would have been—and have proved to be—of the order of 0.15 of a lane.

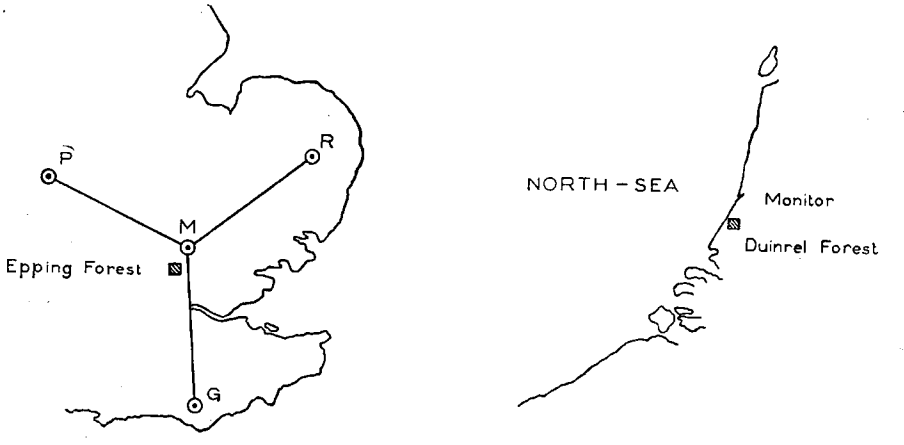



FIG. 1

However the distances to the transmitters were comparatively small.

It is for this reason that similar trials have been carried out in Holland in order to try out the new technique at much larger distances.

**Trials and results in the Netherlands, Aug. 1949 (see fig. 1) :**

Due to very much lower signal strength at these large distances—Master 290 km., Red 210 km., Green 320 km., Purple 360 km.—it proved necessary to use an antenna of 6 1/2 metres (22 feet).

The aerial was set up on a tripod ; setting up of aerial and receiver also less than 1 minute. Like in Epping Forest the aerial was insulated, so that there were no objections in it touching leaves or branches of trees.

The terrain—Duinrel Forest— was comparable with Epping Forest ; height of trees between 60 and 100 feet. A closed circuit traverse was measured to obtain the coordinates of the observation stations in the Netherlands system of coordinates and for each of those stations to be observed by Decca, the Decca coordinates were computed with a propagation speed over land of 299 330 km./sec. and over sea of 299 680 km./sec., these being the most likely values known at the present time.

A monitor was observed at about 10 miles outside the area to correct for small swaying of the patterns radiated by the English Navigation Chain (this Chain is not monitored in G.B. at present).

18 observations have been taken, and after applying the false purple corrections and the monitor corrections these observations were analysed.

In this analysis there is an additional error involved, consisting in the unknown " shift " between the British and Netherlands systems of coordinates.

Observations were taken on Red and Green only, because in this area the angle of cut of the Purple hyperbola is too small.

The result of the analysis is that the standard error corrected for false purple is for Red ± 0.026 lane and for Green ± 0.025 lane, while the "shift" expressed in lanes is Red + 0.102, Green — 0.085 (i.e. about 300 metres). False purple readings varied between + 0.21 and + 0.30 under thick coverage of foliage and high trees; near one tree in an open space of about 100 yards diameter the f.p. reading was + 0.11 and on the top of a dune with only low bushes it was + 0.01.

It should be noticed that the "shift" thus computed may not be regarded as a reliable determination of the difference between the two systems of coordinates, because this determination also includes the remaining errors in the propagation speeds used in the computations of the Decca patterns.

From thousands of obversations made between 1946 and 1949 along the Netherlands coast the most likely shift (of course also including remaining errors in the prop. speed used) has been determined to be + 0.10 (mean (68 %) error ± 0.02) for Red and — 0.05 (mean errors ± 0.03) for Green. This agrees fairly well—within the limits of errors—with the values computed from the Duinrel-trials and this seems to be an indication that there is no systematic error in the corrected Duinrel-readings.

From the monitor-readings, taken for 3 days, the conclusion can be made that there is a small swaying in the patterns Red and Green (Purple was not reliable) of the English Navigation Chain. From the analysis of about 600 monitor readings it has been computed that the standard (68 %) error of one single decometer reading is

± 0.018 for Red,
± 0.009 for Green.

Such a small swaying of the patterns (it should be remembered that all figures given in this report are for DAYLIGHT observations) is of course of no importance at all for navigation purposes. On the other hand it will be clear that a Navigation Chain has to be monitored when survey operations are undertaken.

Comparing the results of the British and Netherlands trials it appears astonishing that the standard errors should be smaller in the Netherlands than in G.B. The explanation to this is that the Decca patterns in the Epping Forest trials have not been monitored; consequently the influence of a small swaying of the patterns is included in the computed Epping-Forest standard errors.

Moreover in comparing both sets of standard errors it should be borne in mind that the number of observations was comparatively small in both cases. The same can be said about the st. error in the stability of the patterns (± 0.018 Red and ± 0.009 Green) as the period of monitoring is too short to eliminate all long-period errors; anyhow the figures will give an idea of the order of magnitude to be expected.

There is one consideration that leads to the conclusion that in actual land-surveying, using this new correction-technique, the standard errors will be smaller than those obtained from these trials. The consideration is that taking the false purple readings is quite difficult and inaccurate with present-day test equipment. Those who have seen the trials will agree to this. However it will be very easy to take more accurate readings with the equipment in its final form.

There is still another reason why in future practice higher accuracy may be obtained, viz. that all trials have been taken with Navigation transmitters and receivers. Survey equipment is designed to higher standards of accuracy.

For these reasons it seems not to be too optimistic to *expect* the following magnitude of standard errors in taking Decca observations in heavily wooded country :

$$\pm\ 0.02 \text{ for } \begin{cases} \text{Red} \\ \text{Green} \\ \text{Purple} \end{cases}$$

Similar trials in the area mentioned in my report of January 1948 (covering the whole of the Netherlands) have been planned for the fall of this year. They will cover Red and Green only (no angle of cut from Purple). Maximum distance to transmitters will be 550 kilometres.

It should be mentioned that in the analysis of the Netherlands trials one observation station has been omitted, because the errors were very irregular for several observations taken at that station, and amounted to 0.1 of a lane maximum.

A reasonable explanation has not yet been found. One possibility is that quite near there is a large trellis-work of barbed wire. Another possibility is that something (for instance ammunition) has been buried underground during the German occupation.

It is the intention to survey the whole area near that station by Decca at intermediate distances of say 10 metres; possibly the disturbing influence may be located.

## CONVERSION OF LANES INTO METRES.

The accuracy of a fix by two intersecting Decca lines expressed in metres depends on :
*a*) The local lane width;
*b*) The angle of cut.

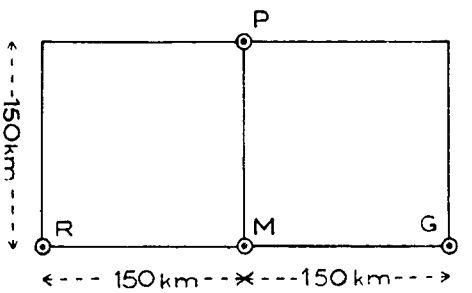


FIG. 2

When a rectangular area has to be surveyed with a 3 slave chain, a location of the transmitters like in fig. 2 is to be preferred (of course when local circumstances permit). As the Chain will be used for survey work in daylight only, a base length of 150 kilometres is acceptable (for base-lines over water more). Thus the area indicated in fig. 2 would be 300 × 150 = 45 000 sq. km. or about 18 000 sq. st. miles. In this area the lane width will vary between 1.400 and 500 metres and the angle of cut between 65° and 90°. Consequently, estimating the standard error at 0.02 lane the worst standard error in the fix will be:

$$\frac{0.02 \times 1400 \times \sqrt{2}}{\sin 65^\circ} = \frac{39}{0.91} = 43 \text{ metres.}$$

and under the most favourable circumstances

$$\frac{0.02 \times 500 \times \sqrt{2}}{\sin 90^\circ} = 14 \text{ metres.}$$

It is very important to note that these errors do not accumulate in a chain of fixes obtained by Decca. This of course is a very big advantage of *all* electronic systems as compared with terrestrial surveying methods where errors always accumulate. It is for this reason—absence of accumulation of errors — that in electronic surveying much larger errors in position fixing can be accepted than in conventional surveying work.

## CONCLUSIONS.

In my opinion this new development of Decca is a very important one, because it opens the way to an absolute new method in land surveying compared with the conventional methods of terrestrial surveying.

It is true of course that the number of observations is still too small to make definite conclusions. There seems to be however no doubt that the principles are sound.

It is true also that at present time the accuracy will be sufficient only for small scale reconnaissance surveys (I have in mind here the correction technique in wooded country only; for Hydrographic surveying and very likely for position fixing in aerial surveys also, position fixing by Decca will be sufficiently accurate in most cases). But when one realizes that this degree of accuracy of 0.02 lane has been achieved after a development of the false purple technique of 3 months only, it seems not to be too optimistic to expect further progress in the future.

Even with standard errors of 0.02 of a lane terrestrial surveying in large areas of jungle country where there is no existing terrestrial triangulation is so much facilitated, speeded up and improved in accuracy, that one may speak of a big step forward in the methods of reconnaissance surveying.

Besides Decca there are other electronic systems for surveying. One of the most important is Shoran. I do not have the intention to compare these two systems in this paper. The choice of a system to a large extent will depend on the nature of the work to be carried out with it. To me there is no doubt for instance that as a (future) substitute for terrestrial primary triangulation over large areas of *land* Shoran is to be preferred above Decca. Both systems have their advantages and disadvantages and with a special surveying project in mind all circumstances have to be studied carefully before making a choice.

All electronic survey systems are very expensive to purchase and to operate and their use will pay only for large mapping projects.

It appears however that only long wave phase-comparison systems like Decca can fulfil several demands — surveying at sea, in the air and in heavily wooded country — at the same time, thus making their use more economical.

## SUPPLEMENTARY REPORT.

In the Aug. 1949 report it has been mentioned that the observations at one station (no. II) have been omitted from the analysis because the differences between corrected (false purple + monitor) Decca-readings and computed Decca-lanes — besides being irregular — were far too large compared with those at the other stations.

The whole area — about 60 yards radius round station II — now has been resurveyed with Decca. In the whole area (including a new station very near the trellis-work) the errors however remained of the order of 0.10 of a lane, having always the same sign. No indication at all was obtained of any strictly local disturbing influence underground nor in the terrain.

After much thought at the end however it turned out that an error had been made in the plotting of the terrestrial coordinates of II and consequently in all surrounding new stations because their coordinates were derived from those of II, resulting in errors in the computed Decca-lanes. After correcting for this error and recomparison with the monitor-readings it showed that during 2 of the previous observations at II the monitor was unstable for about 0.05 of a lane (according to a radiogram : Decca transmissions disturbed 10 h. 51/10 h. 52 on 16 August, being about the time at which the observations were taken). Hence those 2 observations have been cancelled. There now remain 6 previous observations at II and 11 new

observations near that station. These 17 observations have been analyzed with the following results :

standard (68%) error of a single corrected reading Red ± 0.019
— — — — Green ± 0.013

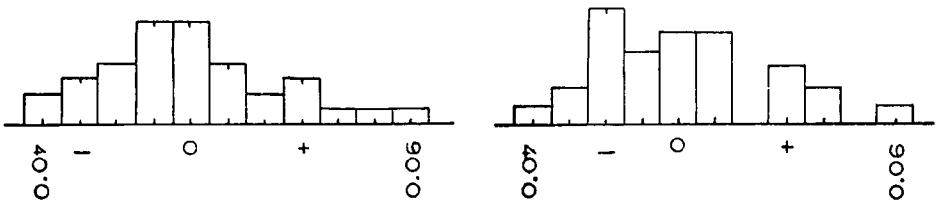
Shift { Red + 0.092 / Green — 0.062

As this result of the area near II is in perfect accordance with the original analysis of the other (18) stations, a new combined analysis has been made of the total of 35 observations in Duinrel-Forest :

standard (68%) error of a single corrected reading Red ± 0.024
— — — — Green ± 0.023

Shift { Red + 0.096 / Green — 0.073

In the computation of the standard errors it has of course been assumed that the errors are of a purely random character. The distribution of errors is shown in the accompanying histograms.




Red Green

Taking into account that the number of observations is small (35 only) it appears that they are indeed of random character, or at least in considerable part. The number of observations is too small for further detailed analysis ; there seems however to be an indication that there is not much chance of improving the accuracy of this method of position-fixing in wooded terrain by taking a very great number of observations within a short period of time, say an hour.

The analysis seems to indicate that there exists some kind of long period influence, possibly of the order of 0.01 of a lane.

It is not unlikely that the Survey Chain equipment may be able to correct for this kind of error.

In addition another important trial has been made outside Duinrel-Forest, (the ground is sandy and very dry in Duinrel-Forest).

The equipment has been tested without any direct earthing contact and with ideal earthing contact in an open canal.

There proved to be no difference at all in the readings R.G. and P., nor in false purple.

This is a very strong indication that this system of land-surveying will work correctly independently of the type of terrain.