CHAPTER 59

A SYSTEM OF RADIO-LOCATION USED IN THE DELTA AREA

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INTRODUCTION

In the South-Western part of the Netherlands the Delta project is being carried out consisting inter alia of 4 main dams closing 4 large inlets (fig.1). Through the four tidal inlets to be closed about 1800 million cubic metres of water run into the Delta area during flood tide and flow out again during ebb tide. This means about 7000 million cubic metres daily.

The bottom of the inlets and the sea-bottom consist of fine sand (d_{50} = .100 - .300 mm), which is in constant movement. During the past centuries considerable changes in the bottom contour have taken place. Yearly many millions of cubic metres of sand are moved by the water. The bottom is a very complicated system of gullies and sandbanks which has evolved down the centuries and is ever changing. It is evident that the dams under construction will out off the tidal flow into and out of the area and that this will result in a considerable change in the sand movement.

The underwater estuary extending as far as 20-25 km seawards from the dams will probably have to adapt itself rather suddenly, i.c., within a few decennia. This can be dangerous for the Western extremities of the islands. The whole combination of phenomena concerned has to be studied and watched very carefully.

Basic information concerning the sand movement and its consequences is given by soundings.

A long term of frequent and accurate soundings with very good repeatability is required for the entire coastal area of the estuary. However, the meteorological conditions for sounding are such that good conditions only obtain on about 20 days a year, because good visibility and a quiet sea must occur simultaneously. Moreover, there is a serious shortage of landmarks and at distances seawards of less than 10 km from the shore visual location is impossible. The only solution is to make the location independent of visibility. For these reasons it was decided that a system of radio-location should be devised. We were advised by an independent expert to adopt the Decca survey system.

With such a system it is possible to make frequent soundings with very good repeatability and with a reasonably low number of launches, because many more suitable days (and nights) become available. This system of radio-location is called the Delta chain. The system is also used for special purposes (velocity and sandtransportmeasurements).

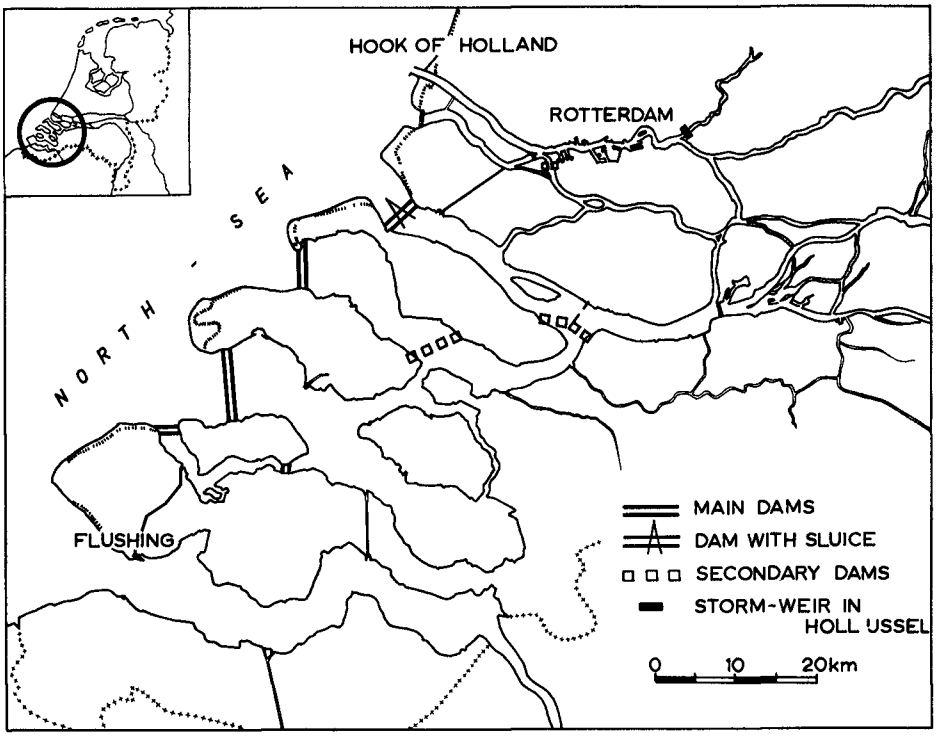

Fig. 1. Plan of the Delta project.

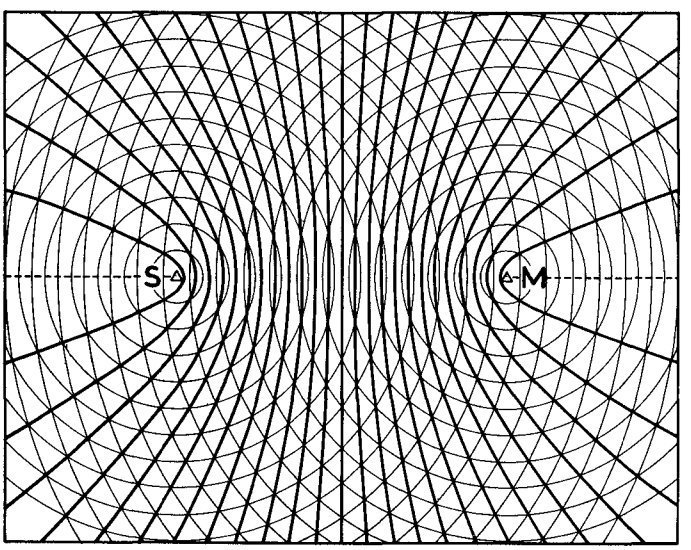

Fig. 2. Shows the way in which the hyperboles are generated. The thin lines are the signals from master and slave, along the thick lines the phase differences are constant in time.

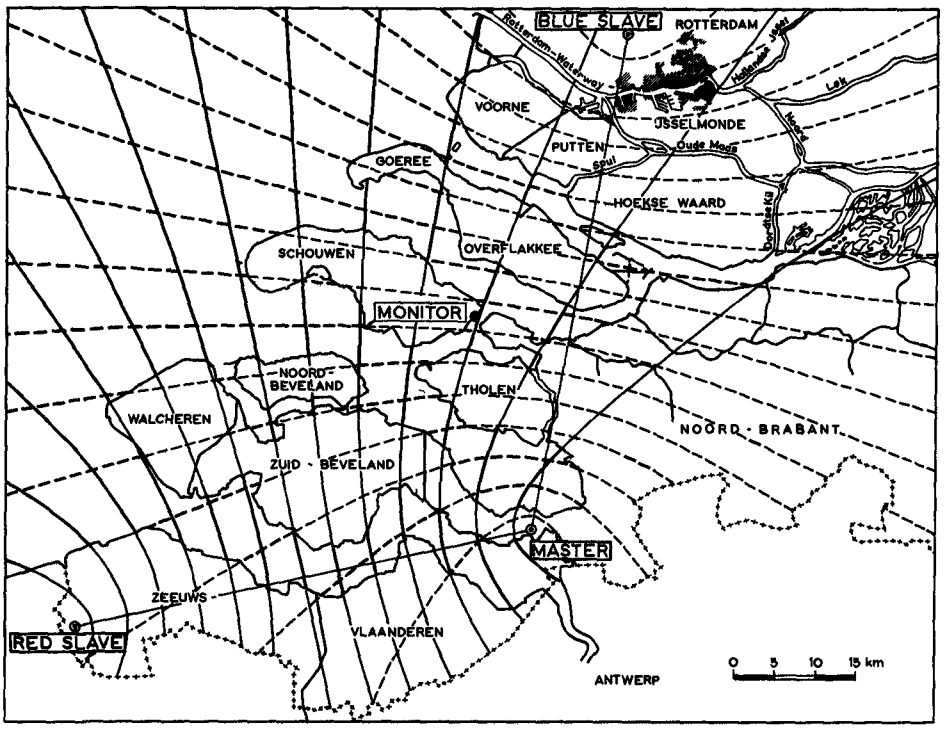

Fig. 3. Lay out of the Delta chain. 1 in 10 of the O-hyperboles is shown.

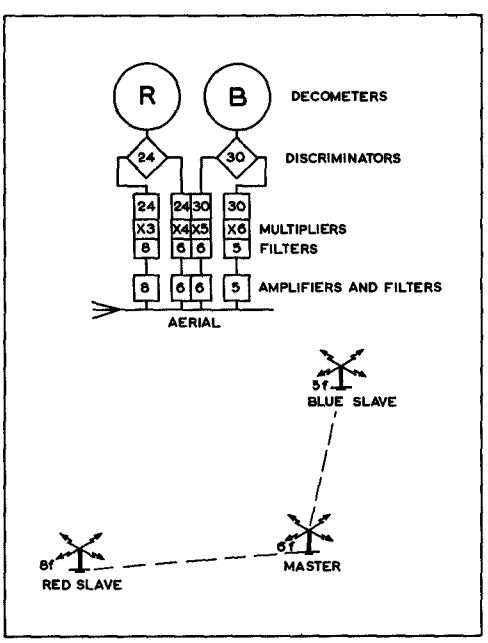

Fig. 4. Diagram showing principle of phase comparison in a receiver.

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THE DELTA CHAIN.

PRINCIPLES.

The Delta chain consists of 3 radio-transmitting stations, viz., a master, a "red" slave and a "blue" slave.

The master and one slave generate a stable stationary wave pattern. The master transmits a continuous radio signal, which is picked up by the slave and this signal is retransmitted in phase with the master but at a frequency different from that of the master signal, so that a receiver can distinguish between the two signals. For the sake of clarity the master and slave signals are shown in Fig.2 as having the same frequency. The hyperbolic lines are the geometric loci where the phase-difference is a constant with time.

The master and the other slave cooperate in a similar way, producing another set of hyperbolic lines.

The locations of the stations and the patterns generated are given in fig.3. Of each pattern 1 in 10 of the hyperbolic lines, where the phase-difference is zero degrees, is shown.
The area between two zero-hyperbolics is called a lane. The stations are so located that maximum accuracy is obtained near the main dams while the hyperbolic lines can be used as guides for taking soundings. With a suitable receiver and a chart with both patterns on it location in terms of hyperbolic coordinates becomes possible.
Measurement by the receiver is fundamentally a matter of phase comparison, the signals of the master being compared with those of each of the slaves.
The signals received are amplified and brought up to the same frequency, set by set, before being compared as shown in fig.4. The results of phase comparison are shown on dials (decometers). one for each pattern. One revolution of the hand is 1 lane (360 degrees). The scale is calibrated in hundredths. The accuracy with which it can be read is 0.002 of a lane; 24 red lanes and 30 blue lanes form a zone. A second hand on the decometer indicates the lane number in a zone and a letter indicates the zone number.

The decometer only gives a direct indication of the parts of a lane involved. Lane number and zone number have to be set by hand before starting.

Because of the rather small lane width a means of lane identification is fitted. So far the Delta chain is the only survey chain fitted with lane identification.

Every minute normal transmitting is interrupted for 0.2 seconds by another combination of frequencies as shown in fig.5. In a similar way as shown in fig.4 the right lane number is shown on a lane identification meter suitable for both patterns. Only the zone number need be known now, but these zones have a width of 10 km or more and are very easy to determine in some other way.

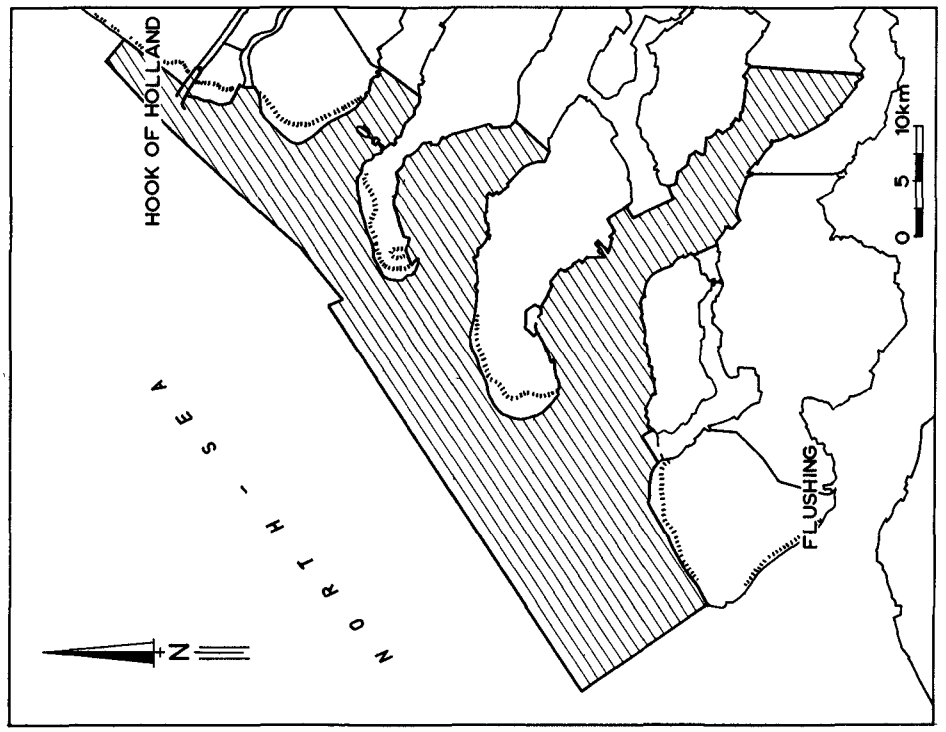

Fig. 6. Sounded area of 300,000 acres, using the Deltachain in 1959.

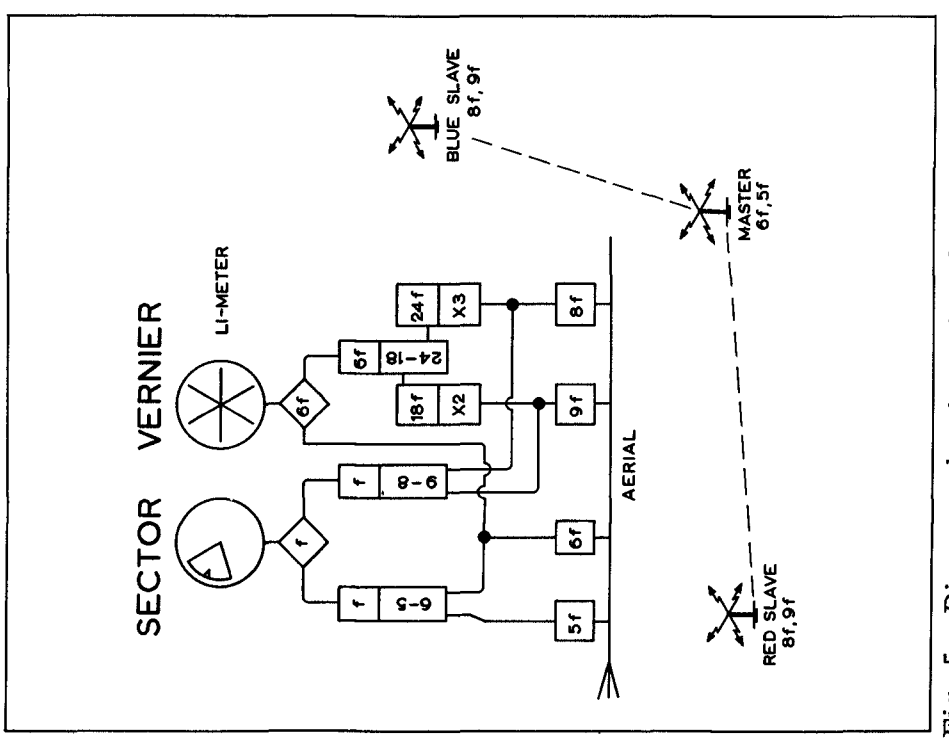

Fig. 5. Diagram showing principle of lane identification measurement in a receiver.

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DATA

The following technical data could be completed and arrived at by counting the lanes, after installing the transmitting stations.

basic frequency f = 14017.5 cycles
frequency: master 6f = 84105.1 cycles
frequency: red slave 8f = 112140.1 cycles
frequency: purple slave 9f = 70087.5 cycles

comparison frequencies: red pattern 24f = 336420 cycles
comparison frequencies: blue pattern 30f = 420525 cycles

propagation speeds of radio waves in the Delta area
over sea V_s = 299674965 m/sec
over polderland V_p = 299504247 m/sec
over dry land V_l = 299437793 m/sec
over dunes V_d = 299300000 m/sec

number of red lanes 129.028
number of blue lanes 172.757

lane width on red base line 445.19 m
lane width on blue base line 356.17 m

length of the base line, red pattern 57441.94 m
length of the base line, blue pattern 61531.05 m
angle between base lines 111°41'16".46

These data could be determined so closely because very accurate terrestrial data were available.

The patterns could be calculated with the above mentioned data. This was done by means of an electronic computor. The coordinates of 300,000 points have been calculated and charts have been drawn to a scale of 1:10,000 showing the patterns calculated.

EXPERIENCE AND ACCURACY

The chain became operational in January 1959, about 10 months after building and fitting started; a trial period also being included.

Besides the three transmitting stations a monitor was fitted up in Zijpe (fig.3) having two receivers and a recorder. From here the two slaves are set and corrected in such a way that the readings correspond with the calculated decca-coordinates at the monitoring station. Normally a discrepancy of plus or minus 0.01 lane is accepted without correcting the patterns. In special cases this tolerance is halved. (0.01 of a lane means 4.45 m on the red base line and 3.56 m on the purple base line).

So far about 10 launches have been equiped with receivers, similar to the monitoring equipment. Two launches have been

fitted with a track-plotter for the rare occasions on which lanes cannot be used for sounding, with these any direction across the patterns can be followed and recorded.

In 1959 a sounding programme was carried out. With 4 launches 11,000 km of developed length was sounded in one season. This whole area is shown in figure 6 and covers about 300,000 acres.

It is very economical to make soundings with the delta chain. The work can be done four times quicker than by the visual method. Speaking generally it can be said that the repeatability of the patterns is very satisfactory, up to a few metres.

The fixed corrections (local differences between real and calculated patterns) have not yet been established, because the receivers are being modified to produce the very accurate results required. An observation programme for estimating the fixed corrections is being prepared and will be carried out after these modifications have been made. The impression is that the maximum fixed corrections will embrace 0.01 lane.

There will be differences between the readings and the calculated coordinates at any spot in the pattern areas. Besides the fixed corrections these differences, expressed in terms of parts of a lane, can be divided up into systematic and random errors. They originate in the equipment, and are due to the atmosphere and local conditions.

SYSTEMATIC ERRORS.

The transmitting equipment is controlled and adjusted by operators at the transmitting and monitoring stations. The errors in the patterns can be eliminated afterwards from the records of the monitoring station.

The receivers need a warming-up period of about one hour. A drift of several hundredths of a lane occurs during that hour. They have great stability within a few thousandths of a lane after the warming-up period. The setting can be checked by means of an internal signal and adjusted if necessary.

It is not possible to check and adjust a receiver for correct readings direct. So a long-term drift cannot be detected by means of absolute comparison. This point will be discussed later.

Atmospheric circumstances such as variations in temperature, humidity of air and soil can influence the propagation speed. The consequence is an increase or decrease in the number of lanes.

Local effects can be of atmospheric origin. A sudden change in propagation speed occurs as the radio waves cross the boundary between land and water, upsetting the pattern locally.

Metal objects (bridges, big ships) can cause errors.

Fixed errors have already been mentioned.

RANDOM ERRORS.

The transmitting equipment (see under systematic errors).

The receivers are stable within 0.003 lane after the warming-up period.

Atmospheric conditions are the main cause of random errors. Static electricity, heavy rain, or glazed frost on the insulators of the aerials can give rise to instability in the whole area or locally. As a rule this instability amounts to 0.02 of a lane and does not make reading impossible. The greatest instability ever noticed was about 0.1 of a lane, making reading impossible, but this very seldom occurs and so far has not lasted for more than about one hour.

Another effect causing instability up to plus and minus 0.05 of a lane is due to fluctuations in what is called the sky wave reflected by the Kennedy-Heaviside layers especially during a period of 1½ hours before and after sunrise and sunset. The patterns are also less stable during the night than they are in the day-time.

These effects vary from place to place and from time to time hence a standard correction cannot be made.

This year a second monitor was fitted up in The Hague for research and checking purposes and some questions have arisen. Are the propagation speeds in the delta area variable from time to time? (The answer seems to be "no" or very nearly so because of the favourable conditions regarding the conductivity. No tidal effect is noticed). Do the small movements of the patterns recorded at the monitor in Zijpe apply to the whole area or are they local? (The answer seems to be: For nearly all of them apply to the entire area; with the exception of sky-wave effects and local static, they can be corrected by using the monitor records).

The monitoring receivers and those in the launches can also be checked for correctness of reading. Since direct checking is not possible, as has already been stated, a relative comparison must be made, especially to detect any long-term drift.

CONCLUSIONS

Some interim conclusions can be made.

Fixed corrections and land-water effects will cause a difference up to 0.02 of a lane between actual and calculated patterns.

Under normal conditions an accuracy of 0.01 of a lane is attainable. It is anticipated that for special purposes an accuracy of 0.005 of a lane can be achieved, using a series of observations.

It is clear that the chain will need careful and continuous watching because of the great number of factors influencing its accuracy.

The chain will be a great help in the Delta works.