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FIFTY YEARS AGO...

The significance of the development of radio acoustic sound ranging in the 1930s is highlighted in the following paper which appeared in the *Hydrographic Review* of November 1932.

"RADIO ACOUSTIC SOUND RANGING

Lecture delivered by Captain G.T. RUDE, U.S. Coast & Geodetic Survey, before the Third International Hydrographic Conference, Monaco, 22nd April, 1932.

As I stated in the Committee meeting, the United States Coast & Geodetic Survey did not suggest this subject on the Agenda for long discussions, but to bring it to the attention of the Conference, and I am empowered by my Bureau to offer the co-operation of the Coast & Geodetic Survey to any of the Member States who may desire to adopt this method in their hydrographic surveys.

In determining position by radio acoustic sound ranging, two hydrophones are anchored along-shore outside the breaker line connected by a cable to a temporary radio station on the beach, through an amplifier which automatically actuates a radio transmitter through a relay or thyratron whenever a sound of sufficient intensity reaches the hydrophone.

For the determination of the survey vessel's position, a bomb, varying in size from a blasting cap to a pound of TNT, is dropped overboard. At the same time a two-pen chronograph is started on the surveying ship, one pen marking the seconds and the other the instant that the explosion from the bomb reaches the chronograph.

The sound from the explosion then proceeds to the two shore hydrophone stations and is automatically flashed back to the radio station on the ship and is recorded on the same tape recording the explosion at the ship. The lapse of time intervals determines the measurement of the distance from the ship to each shore station and can be measured from the tape to within one-hundredth of a second or about 30 metres.

Radio acoustic ranging has proved especially effective on the Pacific Coast of the United States where the narrow continental shelf and absence of offlying shoals lends itself to position determination by this method. Positions are determined with ease 50 to 75 miles off shore, and in one case 206 miles from shore. On the Atlantic Coast, however, the continental shelf with offlying rocks has presented difficulties which have not yet been overcome. It has been necessary on the Atlantic Coast to vary the technique somewhat from that used on the Pacific Coast, especially on Georges Bank. On this survey an origin buoy is anchored about 200 miles off-shore near the edge of the continental shelf in about 30 fathoms of water. The position of this buoy was determined by a long series of star observations within a probable error of about 400 metres. This buoy is held fixed for the purposes of the survey.

A second buoy is planted about 10 miles distant at right angles to the direction of the proposed marine triangulation. A station ship with a hydrophone suspended under the keel is anchored at the origin buoy. The survey vessel then proceeds to the second buoy and passing close aboard drops a bomb in passing. The explosion from this bomb travels to the station ship and back again to the survey vessel in a method similar to that used in the ordinary surveying operations on the Pacific Coast. At least three determinations of this base line are made.

The determination of the azimuth of the line or angle is taken on the survey ship between the sun and the station ship during the day-time; if at night between a suitably located star and the searchlight of the station ship. From this inclined angle the azimuth of the line is determined.

Having determined the length and azimuth of the base line, the triangulation scheme is then extended shorewards along the ridge of the bank by means of quadrilaterals with sides from 10 to 12 miles long with a buoy at the vertices of each triangle. The length of these lines is determined in a similar manner to that in which the base was determined, with occasional azimuths observed along the line to check the computations.

At the completion of the marine triangulation two station ships are then anchored at any two of the buoys, not necessarily contiguous buoys, and the mobile survey vessel then steams along on her sounding line in a manner similar to the Pacific Coast survey, except that the station ships replace the inexpensive shore hydrophone stations. On the survey of Georges Bank many of these lines extended out beyond the edge of the continental shelf to one thousand fathoms, yet the sound travelled back 40 or 50 miles to the station ships and was flashed back by radio to the survey vessel, furnishing a quite accurate position.

In closing, I might mention briefly the cost of the installation. On the survey vessel the cost is about 500 dollars; for the installation of the shore stations about 550 dollars, allowing for the building of a small radio shaft. It must be borne in mind, however, that this method has freed the hydrographer from the limitations imposed by fog and darkness. Now we can sound through the thickest fog and all night. The method has decreased the cost on the Pacific Coast per mile of sounding by fifty per cent."

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As early as the 1930s instruments were developed to facilitate solving the well-known spherical triangle in marine navigation as evidenced by the following information published in the November 1932 issue of the *Hydrographic Review*.

"THE WILLIS NAVIGATING MACHINE

(From information kindly supplied to the Bureau by Messrs. BROWN, Son & FERGUSON, Ltd., 52-58, Darnley Street, Glasgow S. I.)

Among the numerous ingenious instruments recently invented and destined to facilitate air and marine navigation, one, namely the Navigating Machine designed by Edward WILLIS, an American engineer, is of special interest. It is constructed by Messrs. HEATH & C°., New Eltham, London, and was shown at the recent Shipping Exhibition, Olympia.

Fixing a ship's position at sea involves a complicated solution by spherical trigonometry; the WILLIS machine gives the required results in less than one minute as it is, in reality, a calculating machine.

The inventor has improved the construction of the machine since its first appearance and may in future see his way clear to constructing it at the cost price of £ 60, although this is not definite.

Two types of the machine have been presented, one for the use of seamen, the other for aviation purposes. The length is 11 inches; weight of marine type: about 27 lbs.; weight of aviation type: 7 to 8 lbs.; the former is graduated to read to 1' of arc, the latter to 5' of arc.

The instrument should be regarded as a combination of five protractors designed to read simultaneously the five angles of Nautical Astronomy, viz.: Latitude, Declination, Hour Angle, Altitude and Azimuth. In brief, it will solve the well-known spherical triangle *PZX* under all conditions.

The machine is very easy to handle and the students at the School of Navigation, Royal Technical College, Glasgow, were able by its use to work out a great number of problems without difficulty. It was also shown to the Navigation Instructors of the Royal Naval College, who examined it with great interest."

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Automation in the 1930s! An automatic recorder to print signals received from rotating beacons was developed in the early 30s. The following description of this recording apparatus appeared in the *Hydrographic Review* of November 1932.

"AN AUTOMATIC RECORDER OF SIGNALS FROM A ROTATING BEACON TRANSMITTER

By R.L. SMITH-ROSE, D. Sc., Ph. D.
(Extract from *the Nautical Magazine*, Vol. 127, January, 1932)

The present article describes an automatic recording apparatus whereby the signals received from the rotating beacon may be printed on a sheet of paper, thus relieving the need for continuous attention on the part of the operator and avoiding the use of a watch for timing the signals. The instrument is intended to be connected at the output end of the ordinary ship's receiver, and when once it is set in operation the bearing of the distant beacon may be observed immediately, or it may be read off the paper sheet after this is removed from the recorder drum.

The rotating beacon transmitter employs a frame coil about 10 ft, square, rotating about a vertical axis at a uniform speed of one revolution per minute. The coil forms the inductance of a tuned circuit in which the oscillations are generated by the transmitting valve and the intensity of the radiated field at points distant from the transmitter varies as the cosine of the angle between the plane of the coil and the direction of transmission.

As the coil rotates, a characteristic signal is emitted to indicate when the plane of the coil is perpendicular to the geographical meridian. If an observer at a distant receiving station starts a watch or chronograph on hearing this signal, and then observes the time interval which elapses before the signal passes through its minimum intensity, the bearing of the receiver from the transmitter can be calculated from the known speed of rotation of the beacon (6° per second). To avoid having to make this calculation, it is convenient to provide the watch or chronograph with a special dial graduated in degrees (0-360) and also marked with the points of the compass.

Description of the Apparatus. – As the beacon transmitter rotates at its normal speed of one revolution per minute, the pen magnet is energised for almost the whole of the minute, but during the two minima and the space of the characteristic N signal emitted by the beacon it is not so energised. The pen in turn is continuously tracing a line on a rotating drum for these periods when it lifts from the paper.

The drum itself has a circumference of 36 inches, and a ruled piece of paper is fixed to it by a simple clamping device. The ruled lateral marks are 1/10th inch apart, corresponding to degrees. This drum is rotated synchronously with the beacon by means of a phonic motor and gearing, the motor being driven by a standard tuning fork electrically maintained. The pen is mounted on a travelling carriage, which also supports the pen armature and energising magnet. This pen carriage traverses the paper by means of a lead screw geared to the drum, the pitch of the thread being such that the pen moves 1/10th inch per complete revolution of the drum. By this means, the trace obtained is a spiral with a 1/10th inch pitch. To facilitate the final reading of the bearing a movable protractor is fitted, by means of which the bearing can be rapidly read from the trace left on the paper.

In operation, therefore, the drum is rotating continuously, and the pen causes an ink line to be traced upon the paper whenever the strength of the incoming signal is greater than a certain minimum to which the receiver can be adjusted.

When left in operation, the apparatus will continue to record the received signals from the beacon over a period of half an hour or longer, this period being dependent only upon the pitch of the spiral and axial length of the drum. At any time, the received bearings may be read directly off the drum by setting the circular protractor scale so that the 0° reading coincides with the N signal mark, and then noting the reading of the protractor at the mid-points of the gaps in the record which indicate the occurrence of minimum intensity of the received signal.

The pen is lifted from the paper for about 0.5 second corresponding to about 3°, but the mid-point of the minimum space can naturally be measured to within a fraction of this arc.

Accuracy of Bearings obtained with the Apparatus. – To obtain a knowledge of the accuracy of operation of the recorder under practical conditions, a number of tests were carried out at the National Physical Laboratory, Teddington, on the transmissions from the Orfordness beacon.

Since observations of the rotating beacon are normally obtained by an aural observer listening to the incoming signals in a pair of head telephones, it was considered desirable to compare the accuracy of the bearings obtained in this manner by two different aural observers with those given by the automatic recorder.

These results show that the two aural observers are in practically complete agreement in their mean bearings. The mean bearing given by the recorder is seen to be about 0.5° higher than that obtained by the aural observers.

All the above results were obtained at a distance of 93 miles overland from the Orfordness beacon in the presence of severe local interference, and it is likely that when used on board ship under more favourable conditions its operation would be equally reliable up to at least twice this range. It is considered that the recorder could easily be developed along lines which would make it suitable for installation in any part of a ship preferably equipped with a receiver specially tuned in to receive signals from a rotating beacon. If the present alternate five minutes' interval in the transmissions from Orfordness were occupied by those from a second beacon on the same wave-length, then bearings from the two beacons could be recorded on the same instrument at any time."