SHORAN AND THE ELECTRONIC POSITION INDICATOR FOR THE CONTROL OF OFFSHORE HYDROGRAPHIC SURVEYS

By Rear-Admiral Robert F. A. STUDDS, Director U.S.C. and G. Survey

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A number of articles have been written on Shoran and the Electronic Position Indicator as tools to aid the hydrographer in positioning his ship while making Hydrographic Surveys many miles offshore out of sight of land and visual control. These have been generally of a technical nature, describing what makes the system work, and going into details of special circuits and functions.

The two systems under discussion here : Shoran and EPI (Electronic Position Indicator) are similar in many ways, especially the use of them. Their design has been based upon the fact that we can assume that we know the velocity of electromagnetic waves to within a few miles per second. The data supplied by the two systems gives the radial, or actual, distance between the antenna of the surveying ship and those at two fixed, ground control stations. Since the distances from the two control stations are electronically measured, and the positions of the stations are known, the plot of the position is easily accomplished graphically as all lines of position are portions of circular arcs centered on their respective ground station.

Since the two systems are similar in many respects, these points may be brought out first. Both systems are designed to operate on the pulse type of modulation, in which continuous trains of relatively short pulses are transmitted from the ship transmitter, travel through the atmosphere to the ground station and are repeated back to the ship. The round-trip time for each pulse is measured ; and, since the velocity of propagation is known, the distance is easily computed.

The differences between the two systems are as follows : Shoran employs ultra high radio frequencies which tend to limit the length of lines which can be measured. EPI usues a medium frequency which travels to great distances and very long lines can be measured. The Shoran frequencies are three in number, generally set at 230, 250 and 310 megacycles. Three frequencies are required in order to able to obtain two distance measurements simultanously. By a mechanical time sharing system, the ship transmitter sends out a train of about 30 pulses on, say, 230 megacycles. One ground station receiver is tuned to this frequency. It receives the pulses and tranmits them, pulse for pulse, back to the ship on 310 megacycles. The time measuring circuits measure the period between the instant each pulse left the ship and its return from the ground station. During the next very brief interval, the ship transmitter sends out signals on 250 megacycles. These are received at the other ground station and returned to the ship, also on 310 megacycles. The round trip time is measured by another but identical device. The alternations between the two ground stations occur at a rate of ten times per second ; the effect is a nearly stationary pulse on the indicator tube, and the two distances are measured almost simultaneously.

The EPI frequency is very much lower, being 1.85 megacycles. This permits the greater effective range of this system. Two distances are also measured simultaneously, but the time sharing is done electronically, and each distance is measured alternately at a rate of about 41 times per second. The possibility of the use of but a single radio frequency for the system made this type of time sharing mandatory : fortunately it is a relatively simple system.

The ultra high frequencies of *Shoran* limit its useful range to distances somewhat greater than the line-of-sight between the ship and ground station antennas. Since the elevation of the ship antenna can generally be no greater than 100 feet, it is often as little as 15 feet on a launch ; greater distances must be obtained by elevating the ground station.

However, doubling the height of the ground station will add only a small amount to the line-of-sight distance. For instance, if the elevation of a ground station of 225 feet were increased to 441 feet, the gain in distance would be only eight miles. It is true that much greater distances than the line-of-sight range are commonly measured. It has been found by experience that the average useful range is about 50 % greater than the computed value. The actual range is largely affected by weather conditions. Our experience seems to indicate the greatest distances are possible when operating on the cold side of a cold front.

EPI, employing the lower frequency, is affected in useful range only by the distance which the signal of a given strength will travel. Thus, there is no need for establishing a station at elevations much above sea level.

The pulses used in Shoran are extremely short, being of the order of one-half microsecond ; and are transmitted at a rate of 930 per second. As the peak power is about 12 kilowatts, the average power expended at the transmitter is only three watts. In EPI, the pulses are much longer, being about 60 microseconds ; they occur at a rate of 41 per second. Here the peak power is about 12 kilowatts (it may be increased to 18 if necessary) and the average transmitter power requirement is 30 watts.

EPI is a complementary system to Shoran. *Shoran* is used to control surveys within its limited range, the distance offshore varying from 25 to 75 miles according to the elevations available for the ground stations. The minimum range of EPI is about 15 miles, and its maximum range may be as great as 500 miles. As a result there is a large overlapping area for the two systems. Generally, in the overlapping area, shoran control is carried out as far as possible because of its greater accuracy. Shoran, being a war-time development, was not available for adoption by the U. S. Coast and Geodetic Survey until 1945. Its relatively limited range made it imperative to have another system which would serve as a companion instrument to be useful within the limits of Shoran, but to be capable of extending control to at least 300 miles offshore. Such a system was developed by the Coast and Geodetic Survey and installed on a Survey Ship in 1947 when a large amount of field work was accomplished. At that time the procedures for optimum results were formulated. Anyone who is interested in learning more about the technical aspects of these two systems is referred to a technical discussion appearing in the May 1949 issue of the *International Hydrographic Review*, Vol. XXVI No. 1.

The general procedures in the use of Shoran and EPI are similar, for the same type of information is given in each system, though the unit of measurement differs. The installation of the ground stations for the two systems differs materially ; but this subject is discussed in the above referenced article, as well as in the manuals for the systems. The quality of the positions obtained depends upon the accuracy with which the ground stations have been located. It is generally possible, and very desirable, to locate a ground station at or very near a point which has been installed in a triangulation net.

The distance between control stations will depend upon the probable range of the system in that locality. For Shoran, this distance should be not much greater than about eight-tenths of the average line-of-sight distances to be expected from the stations concerned. Stations too close together may give good control, but the service area will be too small ; if they are too far apart the control will suffer and the service area will be small. Shoran stations should be separated by distances ranging between 25 and 50 miles.

With the long ranges possible in EPI control, the ground stations can be separated by distances as great as 250 miles. For best results, this separation is limited to about one-half the maximum distance required in the control. Thus, if we desire to control 500 miles from shore, we should try to place the ground stations about 250 miles apart. This will meet the requirement that the radii of the arcs intersect at angles not much less than 30 degrees. Shorter bases may have to be used, but the quality of the control will be reduced.

The operating manuals for the two systems give in detail the requirements and instructions for establishing the ground stations. They should be followed to the letter for best results. As control stations may be used for several months, or even over a period of several seasons, a few extra days spent in better constructions, not only of the instrument huts but of living quarters and conveniences for the operating personnel, will pay big dividends.

Another point to consider in the selection of a station site is the land area which might come between the station and the service area. We do not know too much about the propagation velocity and attenuation effects over land ; but we do know that there is considerable attenuation of the signal as well as reduction of velocity over land, and that it will change according to the wetness of the ground. We do know much more, not enough to be sure, about the propagation velocity over water. Therefore it is advisable to have the least land possible between the station and the area to be surveyed. It is difficult to determine the effects of a mile or two of land, but the effects of five or six miles are noticeable. Experience has shown that a small land mass (island) within the service area has had effects on position determinations in its « shadow » so small that they cannot be detected.

Last summer, it was found most convenient to have a Shoran installation at each EPI station ; for then the Shoran can be used to calibrate the EPI and, or part of, the survey control. Simultaneous operation of the two systems has no mutual interference. To avoid distortion to EPI signals it is necessary to make sure that the Shoran antenna mast is not in front of the EPI mast.

The first problem after setting up the station is its calibration, to determine the zero check point on the dials. The Shoran station has been set up at a suitable elevation at some 400 or 500 feet from the EPI mast, and to one side so as to be out of the service area. Its position relative to the EPI is known. A Shoran indicator is available and operating on shipboard. The detection (course to be steered) of the perpendicular bisector of this short base line (EPI to Shoran) is computed. The ship is placed on this line, probably best by three-point fixes, and a course maintained so as to keep the ship as close to this line as possible. At a distance of several miles from the stations, simultaneous fixes (or distances) by Shoran and EPI are measured, with the ship proceeding at a moderate speed. These fixes are taken at regular intervals of time, and are continued out to the limit of good signals from the Shoran station, which may be upwards of 30 miles. Since the units of distance measurements are not the same in the two systems, it is convenient to convert all Shoran instruments to microseconds. With all corrections applied to the Shoran distances, these are then converted to microseconds by multiplying by the factor 10.7401 (loop microseconds per statute mile). The Shoran distance is subtracted from the EPI distance. The distance should remain constant over the entire range of calibration, and it will be if the original installation and checking have been carefully done. The mean difference then, is the calibration constant.

It is necessary to calibrate each station on installation as well as when any major component replacement has been made, or when there is some indication of a change. The correction will probably differ for each station and all should be carefully recorded and used whenever that particular station is involved in line or position measurements.

The EPI position is recorded to the nearest tenth microsecond. The Shoran position data is recorded to hundredths of a mile. These are about the smallest units which can be plotted on the scales which are used for the surveys.

The accuracy of the EPI equipment has been determined by a great many tests. These tests have included points at various distances from the ground stations, the closest being about 40 miles, and the farthest about 280 miles. The calibrations at these various points showed no change in correction for distance. The many readings revealed that the average reading was quite accurate ; that, out of a hundred readings at a given point, one might expect to have :

35 with an error less than 15 meters
53 with an error less than 30 meters
72 with an error less than 45 meters
83 with an error less than 60 meters

Of the other 17, the error might be more than 60 meters, and still usable. There are some which are « wild », and so can be rejected, as useless. The actual « wild » readings were a little less than one per hundred.

The minimum range which is practical is about 15 miles (150 loop microseconds). The maximum range used successfully has been a little more than 600 miles. Such great distances cannot generally be obtained ; in this particular case, weather and atmospherics were most favourable. In warm weather, static conditions are often bad, especially at night. Under these conditions, the work is generally planned so that the daytime operations are at the greater distances from the ground stations while the night-time operations are closer to them. A little careful study of the weather conditions and their effect on EPI operations will be very useful.