# CALIBRATION OF LORAC

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Although it should be common knowledge that the accuracy of positions obtained from Lorac or any other electronic positioning system depends on the degree of care exercised in the geodetic positioning of its transmitters and the subsequent calibration of the system, all too often less than adequate procedures are used. Our purpose here is to present calibration techniques considered necessary for optimum Lorac utilization.

The LORAC (LOng Range ACcuracy) electronic positioning system is a phase comparison hyperbolic system using frequencies in the 2 Mhz (mc/s) band. Two versions of Lorac are available. Both have similar characteristics, but differ in the location of the reference station (*). In the older Lorac A (figure 1*a*), only three shore sites — for the master, red slave, and green slave transmitters — are needed, because the red reference station is combined with the green slave and green reference station with the red slave. However, in so locating the reference stations, a serious limitation is placed on the system. Because stable transmission must be maintained between the two slave stations, the distance between them is limited to a maximum of 100 miles, and considerably less in noisy areas. In the Lorac B system (figure 1*b*), the two reference stations are combined at a convenient site somewhere in the vicinity of the master. Although in doing this, four shore sites are required, it does eliminate the need for interslave transmission and as a result, the B system can be set up with longer baselines, permitting better net geometry and greater reliability at extended ranges.

Obviously, the need for an additional shore site for the B system creates additional logistics problems, especially undesirable for a user such as the Oceanographic Office who operates primarily in undeveloped areas. Finding adequate sites is sometimes a problem, and three or four men and a power supply are needed at each site. However, experience has shown

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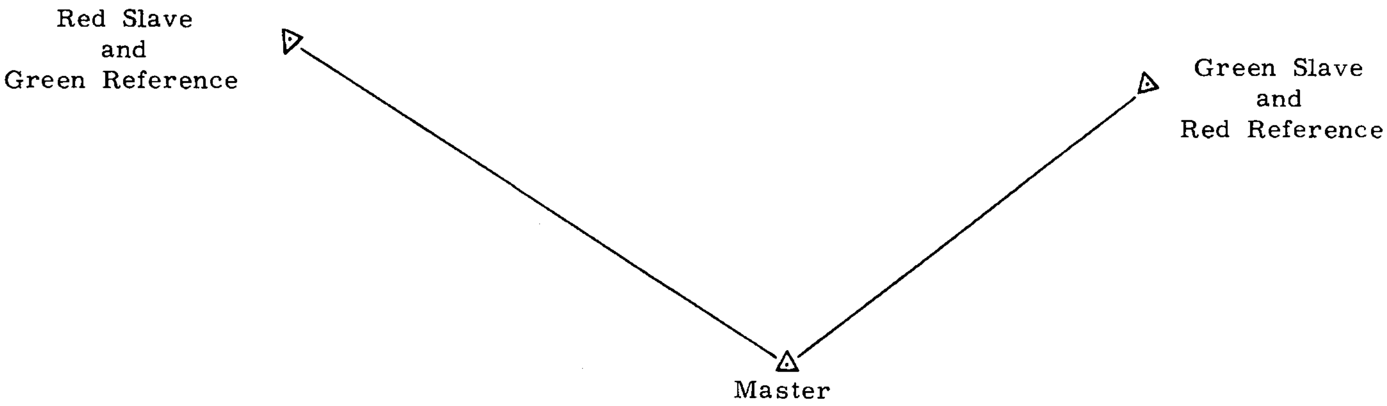
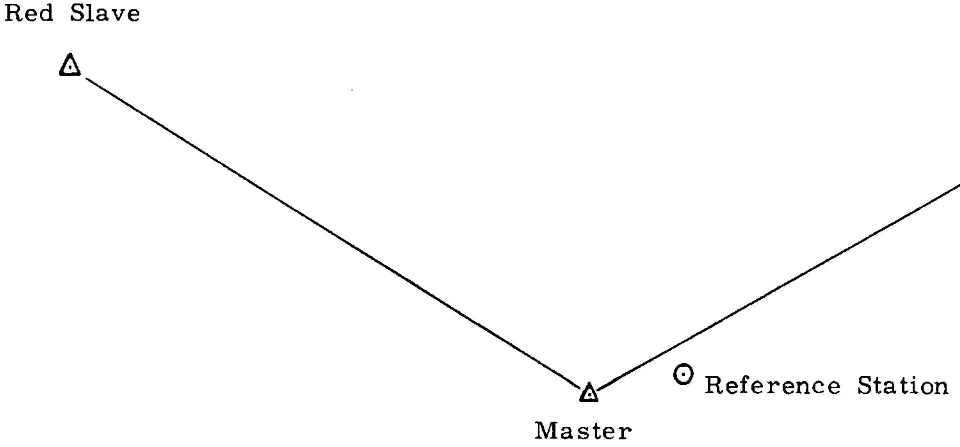
(*) A detailed discussion of the Lorac operating characteristics will be found in *Radio Aids to Maritime Navigation and Hydrography*, I.H.B. Special Pub. No. 39, 2nd edition, Monaco, 1965; Chapter III, Section 6.



a. Lorac A station layout



b. Lorac B station layout

Fig. 1

that the greater range of the B system more than compensates for the additional logistic support, and when a considerable area has to be developed, it can be done with fewer B system nets.

Lorac, in its early days, was subject to a shortcoming common to most phase comparison systems at that time. The system gave a precise read-out of the fractional lane count (to 0.01 lane), but could not indicate positively the total number of whole lanes. The receiver counted the number of completed cycles added or subtracted as the user moved through the lattice, but this count was subject to erros inherent in the counting mechanism. A burst of static or a fluctuation in power could cause an erroneous lane count. This shortcoming was generally handled by having the user when coming into the lattice, go to a known point such as a buoy or other fixed point where he could establish the proper lane count. Whenever an erroneous lane count was suspected, the user would have to return to the buoy, or have the proper lane count carried to him by a helicopter or other vessel.

Within the last few years, automatic lane identification has been developed for the Lorac B system, thereby solving the above-mentioned shortcoming. This Lane Identification System (LIS) is a second system combined with regular Lorac B equipment on a time sharing arrangement. At predetermined intervals, or upon demand, the transmitters alternately emit positioning and LIS signals. The signals occur in a sequence of frequency combinations which produce lane identification in terms of fine (± 5 lanes), medium (±50 lanes), and coarse (±500 lanes). When lane loss is indicated, the operator resets a counter manually until all three lane loss indicator lamps are extinguished, and the error meter reads zero. Fine lane identification is provided continuously. Medium and coarse lane identification are provided automatically every twenty-five minutes.

The first requirement for establishing a precise Lorac positioning system is to tie the electrical center of each transmitting antenna to good geodetic control. Minimum control for a repeatable system requires that the three transmitters, and the reference station of the B system be positioned relative to each other with third order accuracy. If the survey work needs to be tied to specific control or a specific horizontal datum, then the transmitters must also be tied to this datum with third order accuracy.

After the careful positioning of transmitters and the system is in operation, calibration begins. The usual calibration is performed to detect any gross errors in the geodetic work or possibly in the receiver itself. First a receiver is carried across the inner baseline extension (behind the master), where it should be set to zero the minimum reading. Then the receiver is carried across the exterior baseline extension (behind a slave) where the maximum reading is obtained. See figure 2. This maximum number of lanes (whole lanes and fractions) observed should agree quite closely with the geodetic distance (expressed in lanes) between the master and slave. Usually, minor adjustments at the reference station can make the observed number agree with the computed number. Permissible difference between the observed and computed lanes depends on the operating frequency, the

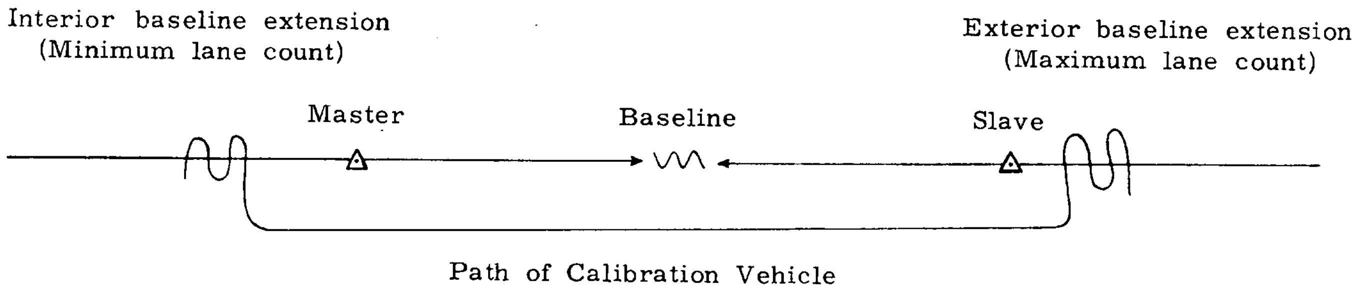


FIG. 2. — Calibration procedure

distance between transmitters, and the order of accuracy desired from the system. The most satisfactory calibration is where the survey ship can cross the baseline extensions, calibrating the receiver to be used in the survey. If this is not practical, then a second receiver is placed in whatever conveyance available such as a vessel, helicopter, plane, or automobile, and carried across the baseline extensions, and then taken to the survey vessel where the correct lane count in transferred.

A Lorac Data Sheet is included below to show an actual calibration.

LORAC DATA SHEET

| | | |
|---|---|---|
| Datum | Provisional South American 1956 | |
| Spheroid | International | |
| Master | Lat.. 3° 18’ 02.12” | |
| | Long. 77° 29’ 49.55” | |
| Red Slave | Lat.. 3° 48’ 46.38” | |
| | Long. 77° 10’ 39.56” | |
| | Red Frequency | 1771.8425 khz |
| | Red Lane Width | 84.570158 m. |
| | Red Baseline Distance | 66850.07 m. |
| Green Slave | Lat.. 2° 57’ 57.68” | |
| | Long. 78° 10’ 19.73” | |
| | Green Frequency | 1797.3325 khz |
| | Green Lane Width | 83.370773 m. |
| | Green Baseline Distance | 83661.98 m. |
| Propagation Speed | 299690 km/sec | |
| Computed Lanes in Red Baseline | 790.455 | |
| Computed Lanes in Green Baseline | 1003.49 | |
| Observed Lanes in Red Baseline | 790.50 | |
| Observed Lanes in Green Baseline | 1003.56 | |

Note that the difference is 0.045 lane in the red baseline and 0.07 in the green baseline. These differences are both less than 1:10,000 or better than second order accuracy.

When greater precision is required, the Dual Crystal method of calibration is used with the Lorac B system. The master, two slaves, and the reference station should all be tied together by a first order survey if possible. In addition a fifth site for a monitor station is selected at some convenient location in the service area of the net, and tied to the other four stations with accuracy comparable to that used in their positioning. This calibration is performed in three steps. The first step is the normal calibration previously described, the second is the receiver calibration, and the third is the so-called geodetic calibration. All calibration should be accomplished during daylight hours, preferably between 1000 and 1600.

The receiver calibration is performed with all receivers to be used in the net. A check should be made to ensure that the net is in stable operation and that all frequencies are correct. The 135 hertz and 315 hertz comparison frequencies must be correct to within 1/4 hertz. Shift the check switch (refer to Lorac receiver operations manual) to RF check. Rotate the green resolver, and adjust to a reading of 0.25 on the green phase meter. Then rotate the red resolver, and adjust to a reading of 0.75 on the red phase meter. Release the check switch. These settings are arbitrary, and are chosen so that the calibration readings may be identified on the recorder charts. This off set will be taken out in the next calibration step.

Now shift the check switch to audio check. The phase meter readings should be within plus or minus 0.01 lane of the RF check readings. If they are not, corrective maintenance will be required to achieve a zero differential phase shift between the RF and IF detector units. All receivers in the net are now calibrated to provide identical differential phase delays through their reference and position signal channels. This condition can be verified at any time during normal operations of the net by shifting the check switch to RF check, and observing that the green and red phase meters are reading 0.25 and 0.75 lanes, respectively.

To calibrate the network to a geodetic reference point, the monitor receiving antenna must be surveyed to the same order of accuracy as the several transmitters of the net, and tied to the same horizontal datum. The lane readings for the monitor antenna position are computed from its geodetic position. Computations must include the following systematic corrections :

1. Third frequency corrections.
2. Average index of refraction correction.
3. Conductivity correction.
4. Receiver calibration correction.

The actual value of the index of refraction must be measured at the time the geodetic calibration is performed, so that the discrepancy between the index of refraction at that time and the average or nominal value can be corrected in the final computations. Otherwise, this discrepancy would appear as a bias. The calibration is based on the average value of the index of refraction. When the system is used for precision positioning, the index of refraction is determined at that time, and a correction for the difference applied to the positions determined. The daily variations will appear in the readings of the monitor station and the users.

The receiver check is now performed again on the reference and monitor receivers. Knowing the correct reading that should be displayed at the monitor site, adjust the reference station phase delays (calibrate 135 and calibrate 315) until the monitor station phase meters show the correct readings. The receivers should be checked again, as in the second calibration step. Record the red and green readings of the reference phase meter.

The net has now been calibrated to a geodetic reference point. This condition can be verified at any time during operations by observing the reference and monitor stations phase meters. They should show the same readings obtained during the original calibration. The monitor readings will fluctuate from time to time due to changes in the index of refraction, but this is normal and an indication of the amount of correction necessary for any position fixes being taken in the service area at that time. Do not adjust the reference station phase delays to compensate for changes in the monitor phase meter unless the reference phase monitor shows the same variation. In this case, repeat the calibration procedure.

The U.S. Naval Oceanographic Office has used Lorac A for many years, and the system provided satisfactory control for hydrographic surveys, in spite of the inconvenience due to the lack of lane identification. Although in recent years, it has not been used extensively in surveying because more convenient and portable systems with ranging as well as hyperbolic modes are now available, Lorac B with LIS is an excellent positioning system and well-suited for permanent or semi-permanent installation. Several nets are in use commercially along the Gulf coast of the United States, and the Navy uses this system for precise inshore tracking at both its Eastern and Western test ranges. Our experience indicates that the system produces a stable repeatable hyperbolic lattic under normal conditions, and when calibrated using the Dual Crystal method, shows good predictability as well as repeatability (*). The exact magnitude of the root mean square error at any point is of course dependent on the net geometry, and to a certain extent on the signal to noise ratio present.

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(*) *Accuracy of Electronic Positioning Systems,* Henry W. BIGELOW, *Supplement to the International Hydrographic Review,* Radio Aids to Maritime Navigation and Hydrography, Vol. 6, September 1965, page 77.