Longitude Without Time

J. W. LUCE

ABSTRACT

A NEW LUNAR METHOD of determining approximate longitude (and coincidentally latitude) without time is presented, explained and illustrated with an example. The method has been specifically designed for emergency use by the practicing marine celestial navigator who normally uses a chronometer and radio time checks but unexpectedly has neither.

The method is simple and does not require measuring the arc between two bodies; simultaneous sights; special tables; prior planning; lengthy or difficult computations; or unusual plotting. It utilizes conventional sextant altitude observations, sight reduction and plotting, and a minimum of additional computation. Accuracy of the method is discussed.

INTRODUCTION

The present decade has seen a new flurry of interest in lunar methods of determining longitude[1, 2, 3, 4, 5, 6, 7, 8]. The practical need for a lunar method seldom occurs in these days of chronometers and radio time signals. However, one drop of even fresh water inside a radio or electronic chronometer will put it out of operation, and so will dead batteries. These possibilities are more likely, and their consequences more severe, the smaller the vessel, and they are most acute on yachts. Whenever any celestial navigator unexpectedly finds himself without GMT, he has only two choices; either "sail down the latitude" or use a lunar method. Historically, the lunar methods have been very difficult, complicated and tedious, and in recent years none has been included in any navigation book.

Mr. Luce of 4336 Dunmore Ave., Apt. 16, Tampa, FL 33611, submitted this paper for publication on January 13, 1976.

For a lunar method to be an effective alternative upon loss of GMT, it should be simple, very quick for the otherwise experienced navigator to learn, and require no prior planning, other than knowing that the method exists and having the instructions on board. It should require only the equipment and skills the navigator ordinarily uses.

PRINCIPLE

The procedure presented here, which has been developed by the author, is based on the suggestion made by Sir Francis Chichester in 1966.[1] It is designed for use with today's Nautical Almanac and Navigation Tables. The principle on which all lunar methods are based is that the moon travels from east to west around the earth at a different rate of speed than do the stars. A timepiece is required, but it does not have to be a Chronometer. If it does not gain or lose more than 35 seconds a day, it will be within a half second for the 20 minutes it takes to get three runs of sights. The important thing is that all the sights be taken with the same watch error even though the magnitude of that error is unknown. However, it is worthwhile to make as accurate an estimate of Watch Error as possible, and this can be done usually within an accuracy of 10 minutes by noting the time of sunrise, sunset or the sun's meridian passage, and with your DR position, consulting the daily pages of the Nautical Almanac.

Basically, this method is quite simple. At morning or evening twilight, sextant altitudes and watch times are taken on the moon and two stars. (The sun and planets should not be used.) The sights are worked up or "reduced" using any of the marine altitude intercept methods such as HO 208, HO 211, HO 214 or HO 229, and plotted in the usual way. Should it happen that the watch time were indeed correct, and the sights accurate, the three lines of position would cross at a single point which would be the ship's actual position. If, however, there is an error in watch time, the moon line will be located a distance due east or west of the star fix, and this distance is proportional to the error in time. This distance is scaled off the plotting sheet and with data from the Nautical Almanac is used for calculating the error in time and for replotting the fix to show the ship's actual position.

Unfortunately, the difference between the speed of the moon's travel and that of the stars is small, so while in theory this method is completely accurate, in practice any error which may occur, such as in the sextant observations or in plotting, is magnified considerably. Therefore, the navigator is obliged to use the utmost care to minimize these errors, realizing that the longitude thus determined will be less accurate than if GMT were known.

PROCEDURE

1. At twilight, take sextant altitudes of the moon and two stars. In the evening, get the moon sights just before twilight, and in the morning, get the moon as soon as the stars disappear. Try to select two stars whose bearings differ by about 90°. Take a run of sights on each body in quick succession recording just the watch times and sextant readings. Try to get about six sights within five minutes on each body, but take enough time on each sight to be accurate.

2. For each run of sights, plot their times and altitudes on a sheet of graph paper, compute the correct slope of the line of sights using the HO 214 "Delta T" method described in paragraph 1507 of Bowditch.[9] Reject any obviously bad sights, and then draw a best fit line of this slope through the remaining sights. Select a point near the middle of this line and determine its time and altitude. Use this point rather than one of the actual sextant readings for your computations. Fig. 1 shows how this is done.

3. Apply all corrections described in Chapter 16 of Bowditch[9] to the three "sights" selected, work them up in your usual way and plot them on a plotting sheet. Be sure also to advance or retire two of these lines according to the course and speed of the ship.

4. Measure the difference of Longitude (dLo) in minutes due east or west between the intersection of the two star lines and the moon line, using the scale at the top or bottom of the plotting sheet.

5. Calculate the error in Longitude (eLo) as follows:

$$\frac{902.46 \times dLo}{43.46 - "v"} = eLo$$

where:

dLo is from Step 4 above.

902.46 is the hourly increase in the GHA of Aries in minutes, on which the Nautical Almanac is based.

43.46 is the difference in minutes between the hourly increases in the GHA's of Aries and the Moon, on which the Nautical Almanac is based.

"v" is the increment in GHA of the moon obtained from the daily pages of the Nautical Almanac for the nearest Greenwich date and hour of the observation.

eLo is the number of minutes of Longitude which the intersection of the two star lines must be moved east or west to plot the ship's position. The star line intersection is moved in the direction toward and past the moon line.

6. Calculate Watch Error (WE) as follows:

$$eLo \times 4 = \text{WE in seconds of time.}$$

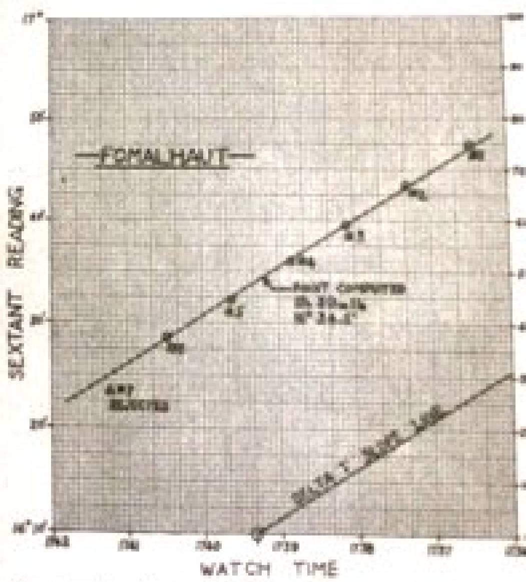

Fig. 1 – Watch time and sextant altitudes are plotted for each run of sights. Correct slope of run is calculated, obviously defective sights are rejected, and good ones are averaged graphically. A point on the line, rather than one of the sights, is used in computation.

When the moon line lies east of the star fix, the watch is fast, and when west, the watch is slow.

If the *dLo* correction turns out to be very large, it is worthwhile to apply the watch error thus found to the watch time of each sight, and recompute and replot all three sights using the same sextant data. Draw a new line through each run-of-sights plot if the value of Delta T changes. This procedure can't reduce errors in the sextant readings but it will reduce to a minimum the errors due to computation and plotting. All navigation is a series of successive approximations and this method is no exception.

Due to the magnification of any errors in the sights and plotting, this method should not be used if GMT is known, but in the absence of GMT, it is the best alternative. It is most accurate when the moon bears due east or west and also when the value of "v" is small. Under these conditions, errors are magnified 21 times. When "v" is at its maximum, the errors are magnified 35 times. When the moon's bearing is 37° away from east or west, these errors are 25% larger and become 26 and 44 respectively.

The latitude of the fix is not affected in this way and has the same accuracy as a normal fix would have. When the moon's bearing is near north or south, this method cannot be used.

Note that this method makes use of two stars only, contrary to the navigator's usual penchant for a three body fix. This is because the three body fix provides the navigator with reliability rather than accuracy. If the triangle formed by three star lines is small, the navigator assumes that none of the sights contains appreciable error and he is proud of himself. If the triangle is large, it does not mean that the ship's position is in the center of that triangle but rather that one or more of those position lines contains substantial error without any indication of which. In this method, reliability is achieved along with maximum accuracy by plotting a run of sights, rejecting any defective ones and averaging the good ones, two good sights being preferable to any number of doubtful ones. Besides, the duration of twilight often is not long enough to get good runs on more than two stars.

Statistically, the moon will be in a favorable

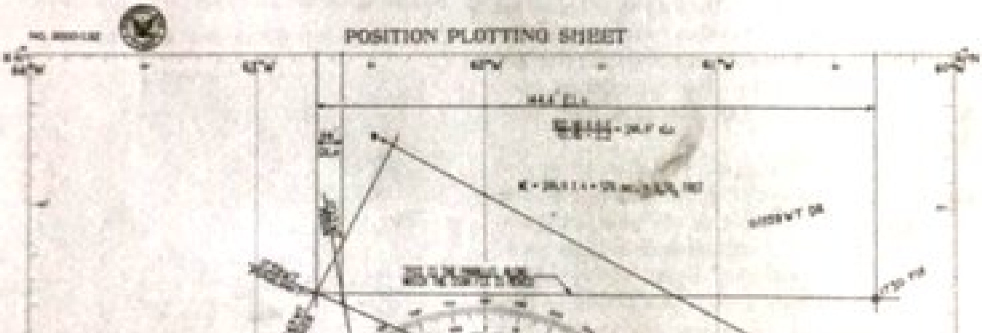

Fig. 2 – Two star lines and a moon line are plotted. All three contain unknown but identical watch error. Watch error and error in longitude are calculated using Nautical Almanac data.

position for this method only about half the time. However, usually within about three days it will move into a usable position either morning or evening. When you have once used this method to obtain a fix and determine watch error, you can correct for this watch error and take observations in the usual way if the moon is moving into an unfavorable position and the watch rate is known.

EXAMPLE

Consider a ship hove to in the North Atlantic on Sunday, January 6, 1974, in DR position 60°51′W and 40°27′N. At evening twilight the navigator, using his wristwatch which is keeping approximate Zone 4 time but with an unknown error, obtains three runs of sights which, after all corrections have been made are:

Body	*Watch Time*	*Altitude*	*Bearing*
Moon	17h23m30s	23°52.0′	080°
Fomalhaut	17h39m11s	16°34.5′	200°
Deneb	17h42m54s	47°21.5′	300°

These are worked up (using HO 214 in this example) and plotted in Fig. 2. *dLo* is measured and found to be 6.6′ which results in an *eLo* of 144.4′. The star LOP intersection is moved this distance due east toward and past the moon line to yield the fix. The watch error is calculated and found to be 9m38s fast.

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