LORAN RECEIVING EQUIPMENT FOR THE MARINER

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The use of loran, which was first developed to meet a military need during World War II, is no longer restricted to the military services. Numerous commercial shipping and overseas air-transport companies now rely on this well-established highly accurate, long-range navigational aid known as loran — an abbreviation for *LO*ng *RA*nge *N*avigation.

There are now in operation a total of 17 government-operated loran transmitting stations in the Atlantic and 36 stations in the Pacific, forming a network which provides loran coverage 24 hours a day over most of the important ocean routes of the North Atlantic and Pacific Oceans. These transmitters are operated by various countries as follows:

Country	*Number of Stations*
Canada	6
Denmark	2
Iceland	1
United Kingdom	1
United States	43
Total	53

The international scope of loran is indicated by the fact that modern loran receiving equipment can be found aboard ships carrying the flags of 14 nations listed below:

Brasil, Canada, Denmark, France, Iceland, Italy, Japan, Liberia, Netherlands, Norway, Panama, Sweden, United Kingdom, United States.

The purpose of this paper is to describe loran receiving equipment for marine use, with particular reference to Mark 2 Mod. 2 direct-reading units currently being manufactured in considerable numbers for both commercial and military use. Since the receiver is only one part of the loran system it may be well to review briefly how the system operates.

Principle of Operation

From a pair of shore-based stations (master and slave) a series of accurately synchronized radio pulses of short duration are radiated in all directions.. The spacing between the master and slave stations is usually from 200 to 400 miles.

These signals are received aboard ship by means of a special receiver-indicator with which it is possible, first to select and identify each pair of stations by their radio frequency (1950 or 1850 kc) and pulse recurrence rate (somewhere

(1) Division of The Sperry Corporation, Great Neck, New York, U.S.A.

between 25 and 34-1/9 pulses per second) and, second, to measure the time difference which elapses between the arrival at the receiver of the signals from the two stations.

This time difference is used to determine from a loran chart, or book of tables, that the ship is somewhere on a particular line of position on the earth's surface. From a different pair of stations another line of position is obtained The intersection of two, or more, such lines determines the ship's position and the latitude and longitude is obtained from the coordinates of the chart.

Radio waves travel at the speed of light and in one millionth of a second, referred to as a microsecond, a radio wave travels 983.2 feet. The loran receiver-indicator is capable of accurately measuring time in microseconds, which is a direct measure of the distance traveled by a radio pulse during that time. Note that it is not possible to measure the distance from the ship to either of the two stations. The time difference measured is a function of the difference in these two distances. There are many points on the earth's surface where the difference between these two distances is the same. These points lie on a hyperbolic curve which is but one of a family of hyperbolic curves for which the two transmitting stations are the focal points. Because of a constant difference in distance the same time difference is obtained everywhere on each loran line of position.

Loran lines are printed on navigational charts, and they can be plotted from books of tables. The data for the lines are precomputed by the U.S. Navy Hydrographic Office, which published the tables (H.O. 221 series) and charts. Because of the increasing use being made of this system, loran lines have been added to many of the standard nautical charts issued by the U.S. Coast and Geodetic Survey (2).

Ship Equipment.

The components of the Mark 2 Mod. 2 direct-reading loran receiver equipment are shown in Fig. 1. The receiver-indicator is shown in greater detail in Fig. 2. Loran receivers vary in design depending on the manufacturer but certain essential features are common to all.

The receiver-indicator includes a superheterodyne radio receiver, but instead of the signals being made audible they are displayed on a cathode-ray tube, or scope. The functions of the receiver-indicator are to select and identify the signals from various stations, and to measure the time difference in microseconds which elapses between the arrival of the signals from the master station and the arrival of the signal from the slave station.

The equipment also includes a power supply which contains rectifier and electronic voltage regulator circuits for supplying the proper voltages to the receiver-indicator. The power supply is frequently a separate unit. Most shipboard sets require single-phase, 60-cycle, 115-volt current and draw less than 300 watts. For ships having a d-c supply a rotary converter or motor generator is employed to convert the ship's d-c to a-c power.

The antenna consists of a wire, preferably vertical and from 35 to 125 feet in length, supported from some high point on the ship. A coaxial cable is used

(2) See *International Hydrographic Review,* Vol. XXIX, No. 2, Nov. 1952, page 75.

to connect the receiver to the antenna which is broadly tuned to the correct band of frequencies by means of an antenna coupler. This consists of a tapped coil in a small box and is installed near the lower end of the antenna.

Direct-Reading Loran Receiving Equipment.

On the various loran receivers available during World War II, after the two signals had been superimposed it was then necessary to go through several additional steps to determine the time-difference. This was usually done in three steps, and required counting time markers (vertical lines on the scope), multiplying by the value of the markers, and adding three values to obtain the time-difference. Although this process was not difficult to learn it was rather laborious and subject to human error.

Many of the pip-counting equipments are still in use, but none have been manufactured since the end of World War II, as the development of direct-reading lorans have made the pip-counting equipment quite obsolete.

Direct-reading receiver units, like the Mark I unit shown in Fig. 3, were first developed for the U.S. Navy the Sperry Gyroscope Company during World War II and, with the U.S. Navy's permission, were made available to merchant shipping early in 1946. This unit marked an important advance in the art, because as soon as a pulse match had been made the time difference in micro-seconds could be read directly from numbers on a counter.

The Mark I loran has been superseded by the Mark 2 Mod. 1 and more recently by the Mark 2 Mod. 2, shown in Fig. 1.

Features of New Receiving Equipment

The Mark 2 Mod. 2 equipment retains the direct-reading feature and includes a number of advantages over its predecessors.

Trunnion mounting permits tilting the control panel to any angle desired by the operator. The size has been reduced through the use of miniature tubes and by separating the power supply from the receiver-indicator, thus making the equipment unit suitable for installation where space is limited. The receiver-indicator is normally mounted on a table or shelf (Fig. 4). However, the legs can be turned 90° for bolting to a bulkhead (Fig. 5). With an additional cast-aluminum pedestal it can be mounted on the deck (Fig. 6).

Another improvement which has greatly simplified pulse matching is automatic frequency control (or AFC). This enables the incoming signals to monitor the timer oscillator frequency and synchronize the sweep with the pulse recurrence rate of the master station. AFC facilitates placing the master station pulse at the proper position on the top trace and prevents this pulse from drifting. Without AFC it would be necessary to make frequent adjustments of the drift control knob to keep the pulses in view. The AFC is particularly useful for « homing » on a loran line as it is capable of holding the master pulse in the center of the fast sweep indefinitely. If a ship's course cuts across a family of loran lines the AFC will hold the master pulse locked in place, and by turning two knobs a reading can be obtained in a few seconds to check the distance traveled.

A unique feature of the Sperry loran is a motor-operated, continuous, time-delay mechanism. This is obtained by three cascaded selector channels and three phase-shifting resolvers geared together. This gear train, which can be operated either by a motor or manually, provides an uninterrupted movement of the bottom pedestal continuously variable over the entire measuring range. Movement of the bottom pedestal in coarse and fine steps has been elimniated, thus making pulse matching a very simple and straightforward process.

The control panel (shown in Fig. 7) includes the operator's controls, scope, and time-difference indicator.

The scope face is recessed and can be seen in a brightly lighted chart room. A green light filter, mounted at an angle to the scope face, prevents reflections and improves scope visibility. The time-difference indicator and station selector characters can be read in the dark as they are illuminated with a source of « Black Light » (ultra-violet) which minimizes interference with night vision.

A test switch on the control panel enables the operator to check the equipment and assure himself that the readings are dependable and accurate. The test switch also aids the technician when servicing is required. Service facilities are provided by the manufacturer in ports in various parts of the world.

Obtaining a Loran Reading

When a ship is equipped with loran it is preferable that its deck officers receive a course of training in its operation offered by the manufacturer at no charge at schools maintained in several ports in the United States. Similar training is also provided by the U.S. Maritime Administration. Deck officers should have a complete understanding of the capabilities and limitations of loran, and be able to evaluate the accuracy to be expected with loran under a given set of conditions.

Loran lines of position for the several pairs of stations most useful in a given area are printed on charts, the lines for the several station pairs being printed in different colors. A simplified chart is illustrated in Fig. 8. On actual charts the lines may be spaced at various time difference intervals such as 5, 10, 20, 50 or 100 microseconds, depending on the scale of the chart. Each line is marked with three station characters such as 1H3 — 1 representing the Channel (frequency); H and 3 the Basic and Specific pulse recurrence rates for that family of lines. The station characters are followed by the time difference, usually a four digit number, which is constant for all points on that line.

Obtaining a loran reading is easy and with a limited amount of training ordinarily can be accomplished in two or three minutes. With practice on a direct-reading receiver a ground-wave match can be made and the time difference read in as little as 30 seconds. More time is required at night if sky waves are used.

The three station characters for a family of lines selected by the navigator are set in the Station Selectors (see Fig. 7). The signals from this pair of stations (two vertical lines) will then be stationary on the scope, whereas the signals from other stations within range will be drifting either to the right or left along two horizontal lines called traces.

The matching process varies with different receivers but is basically as illustrated in Fig. 9, the object being to superimpose two signals and line up

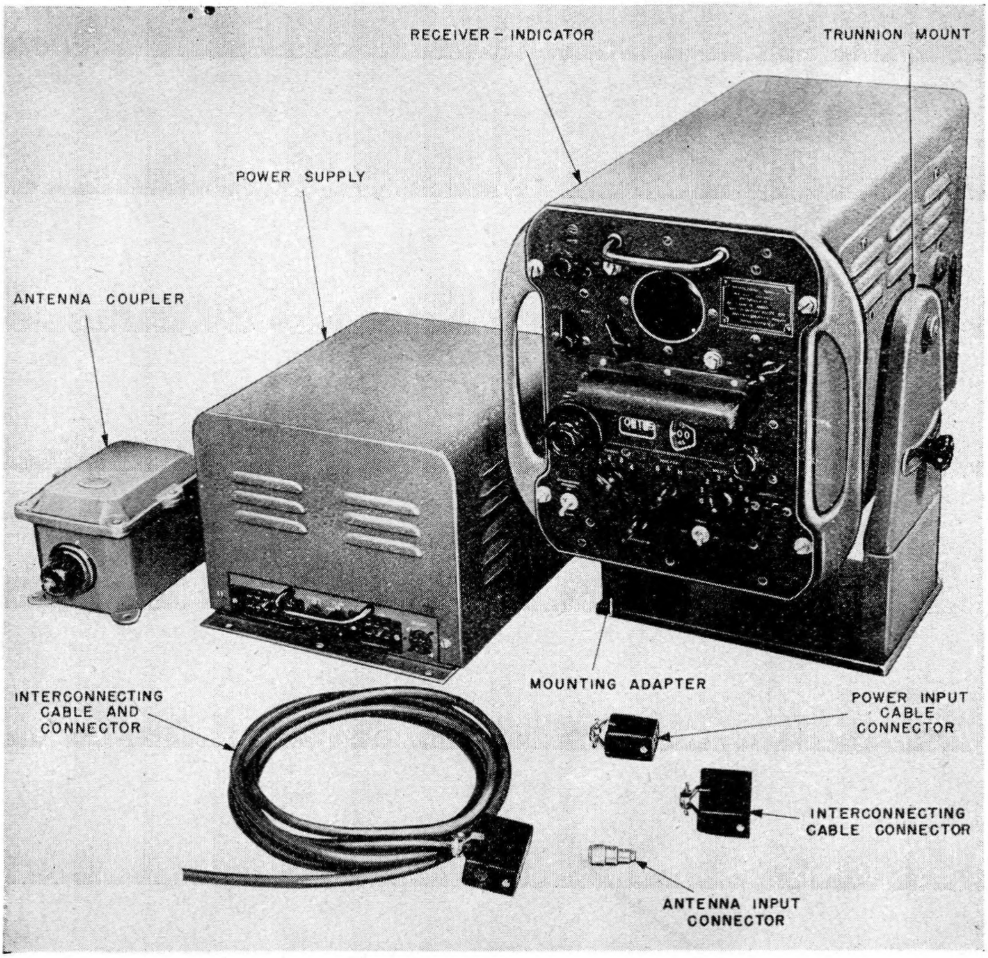

Fig. 1.

Mark 2 Mod. 2 direct-reading marine Loran receiving equipment manufactured by Sperry Gyroscope Company, Great Neck, N. Y. Major components (from right to left) are receiver-indicator with panel cover, power supply, and antenna coupler.

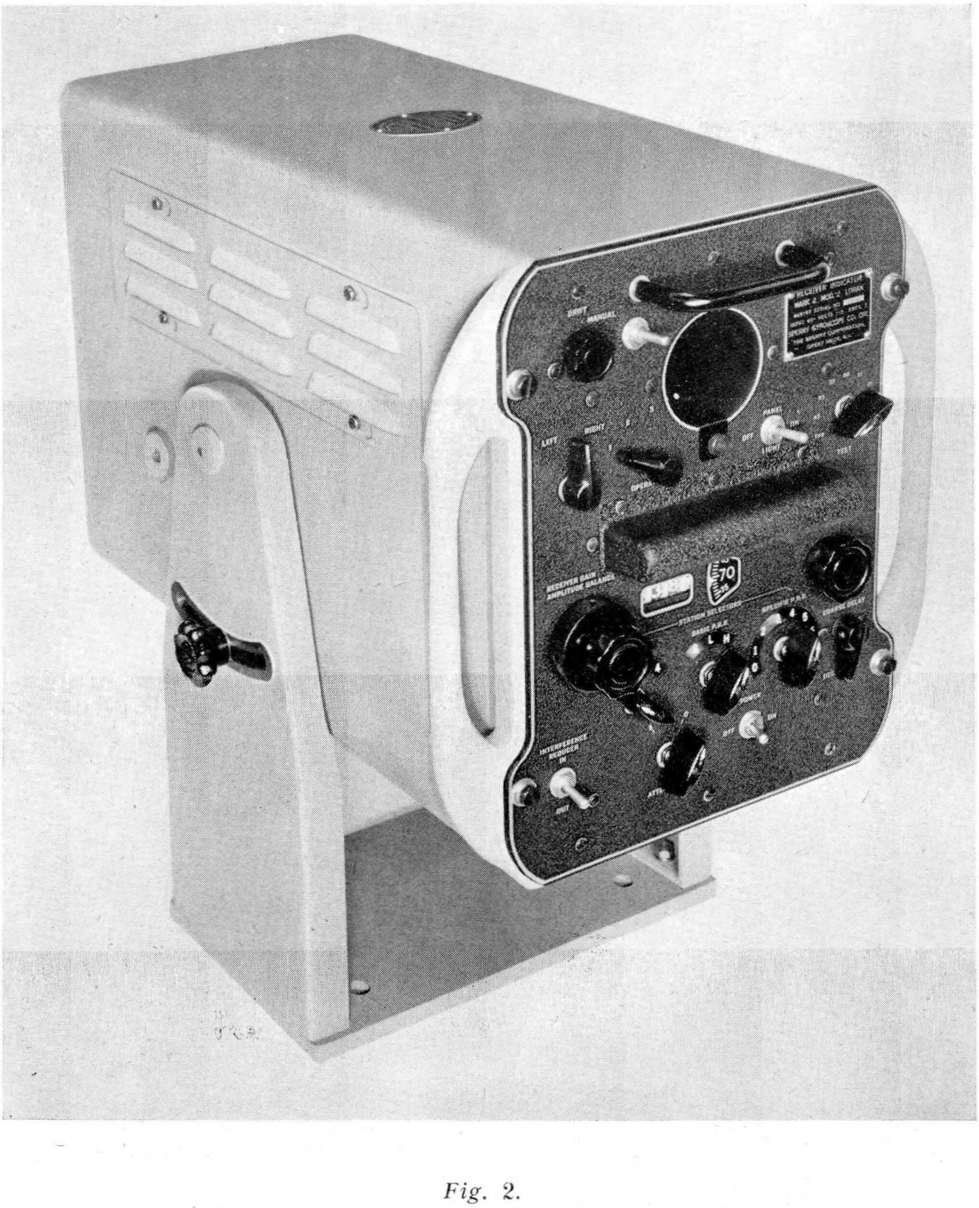

Fig. 2.

Marine Loran receiver-indicator like that shown are used on passenger and cargo, tankers, yachts and fishing vessels.

Fig. 3.

This Mark 1 Mod. 1 Marine Loran receiver is typical of the first direct-reading Loran produced. It was developed for the U.S. Navy by Sperry Gyroscope Company, Great Neck, New York.

Fig. **4.**

Trunnion mounting makes the Marine Loran suitable for table or shelf mounting. Installation shown is aboard the Cunard Line HMS *Queen Elizabeth.*

Fig. 5.

If space is limited the legs can be turned 90 degrees and the Loran mounted on a bulhead as was done on the M/V *William J. O'Brien,* a trawler operating out of Boston.

Fig. 6.

The Loran receiver-indicator may be bolted to a cast aluminium pedestal for deck mounting as done aboard the S/S *Seatrain Louisiana* which hauls freight cars between New York and ports in the Gulf of Mexico.

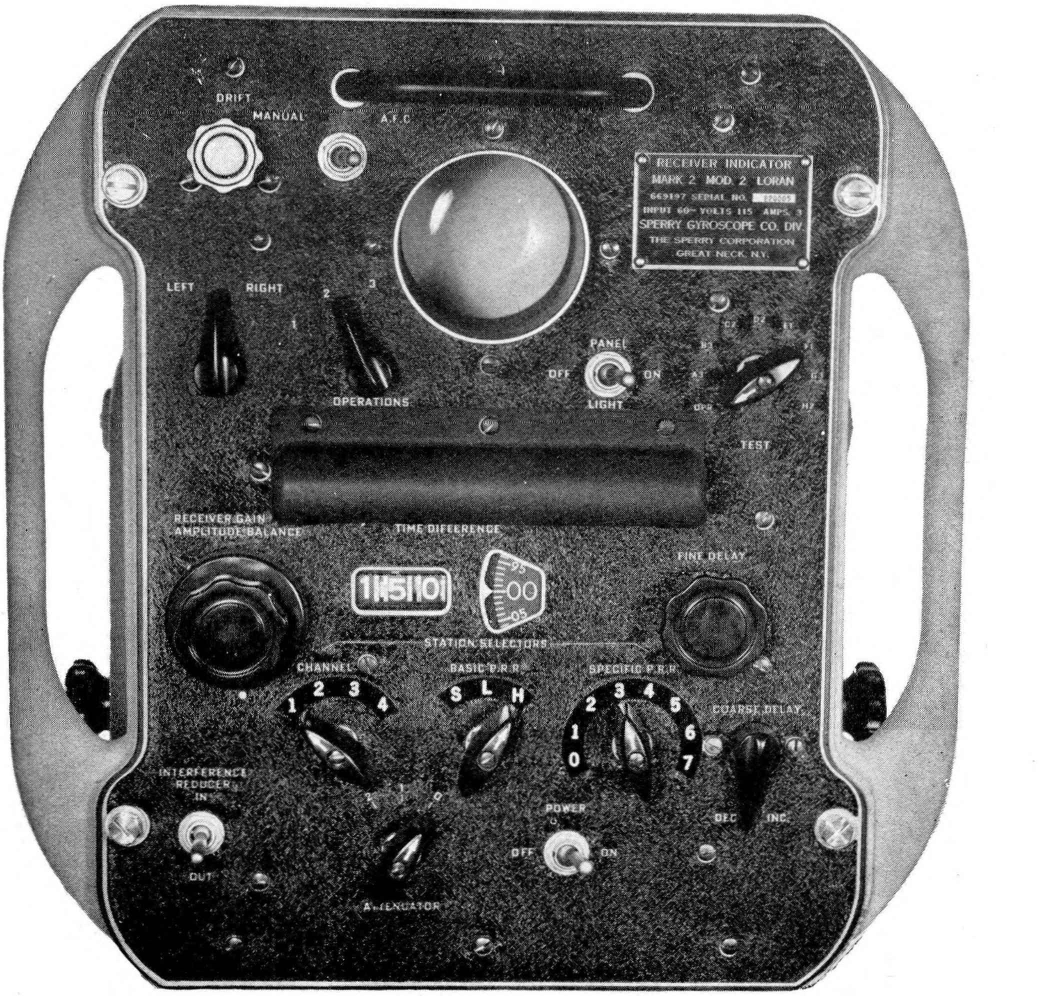

Fig. 7.

Control of this direct-reading Loran features:
(1) Black-lighted, time-difference indicator.
(2) Automatic control of timer frequency.
(3) Motor driven, continuous, time delay and
(4) Self contained test circuit.

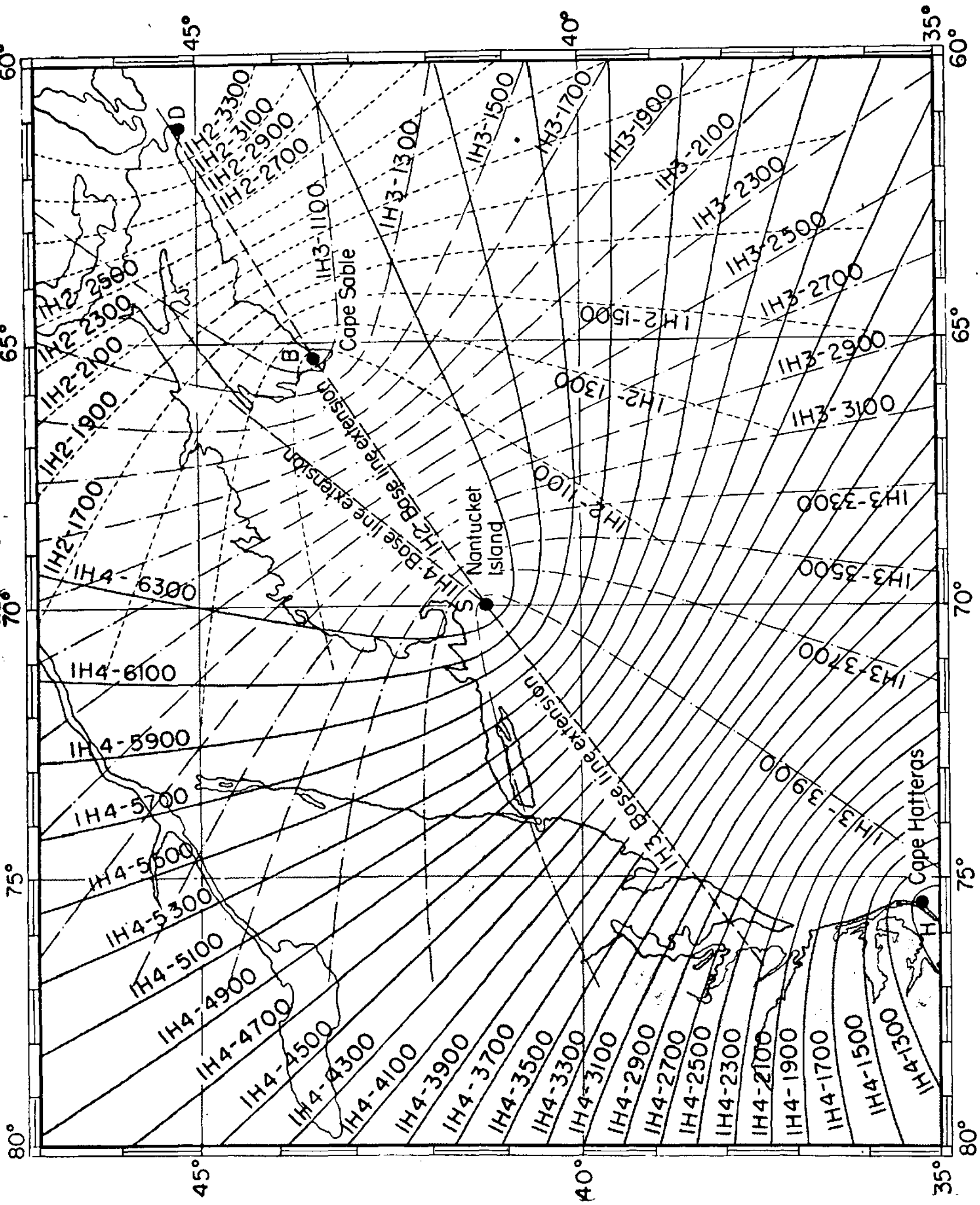

Fig. 8 — Simplified Loran chart showing Loran lines for station rates 1H2, 1H3 and 1H4. An additional station at Sandy Hook, NJ., not shown on the above chart, provides another set of lines (1H0 rate) which, crossed with the 1H4 lines, gives excellent fixes for ships approaching New York Harbor and Chesapeake Bay.

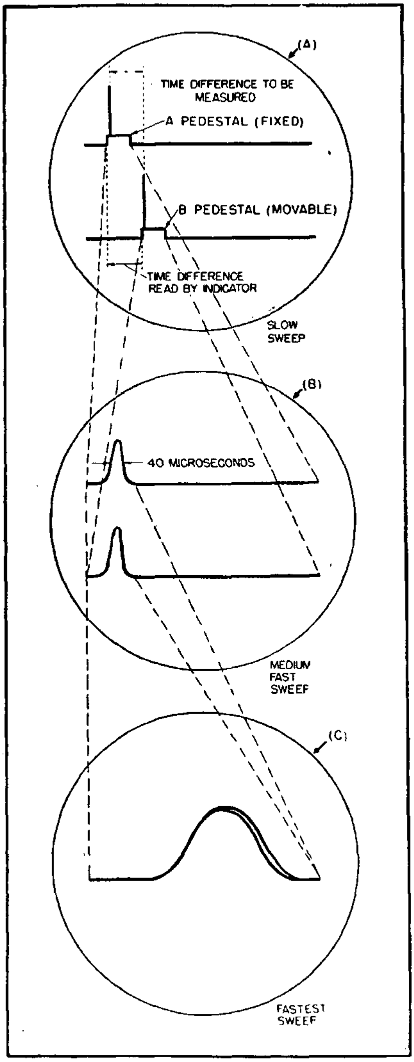

Fig. 9.

Scope presentation illustrating the three operations whereby the signals from the master and slave stations are superimposed.

their left edges. With the Left-Right control in the first step, Fig. 9A, the signal from the master station (a vertical line) is placed on the top pedestal, a raised portion of the top trace. The lower pedestal, which can be moved horizontally with the Coarse and Fine Delay controls, is next placed under the slave signal (a vertical line on the lower trace). In the second step, only the tops of the two pedestals appear, as seen in Fig. 9B. The two signals are then lined up vertically and placed near the left ends of the two traces with the Fine Delay and Left-Right controls. In the third step, Fig. 9C, the heights of the two pulses are equalized with the Receiver Gain and Amplitude Balance controls and the left edges superimposed with the Fine Delay control. This completes the matching process. The time difference can then be read from the time-difference indicator, a reading of 3870 microseconds being indicated in Fig. 7.

Advantages of Loran

The favorable acceptance given this long-range navigational aid by shipping personnel can no doubt be attributed to the fact that the system has many inherent advantages.

Loran makes it possible to determine the latitude and longitude of a ship, or plane, in any kind of sea and in thick weather, when poor visibility makes celestial observations impossible.

The effective range of the system over water at night is about 1400 nautical miles and in daylight from 700 to 900 nautical miles, depending on the power of the stations. At night the range is greater because then the signals upon striking the ionosphere are reflected back to the earth and are received as sky waves.

The accuracy of a loran line of position is of a high order and is comparable to that normally expected from good celestial observations.

An experienced operator seldom requires more than two to three minutes to obtain a fix, a small fraction of the time required with celestial methods.

Loran does not require a knowledge of the ship's heading or dead reckoning position and is completely independent of other mechanical and electronic devices, including the compass and chronometer.

The receiver requires no special calibration because, unlike radio direction finders, loran is not affected by changes in the arrangement of shipboard antenna, cargo booms, ventilators, etc.

The system is free from ambiguity and in case of transmitter-operating difficulties a signal-trouble blink warns the user not to take a reading until the blinking stops.

Because of the pulse transmission used, many loran stations adjacent to earth other can be operated on the same frequency. For example, all 17 loran stations in the North Atlantic transmit at 1950-kc. In the entire Pacific only two frequencies are used: 1950, and 1850-kc. Consol and continuous wave systems (such as Decca, Lorac, and Raydist) require a different frequency for each station.

A loran line, or lines, can be used in combination with terrestrial bearings obtained by visual or radio means, sun lines, star lines, depth curves and radar ranges.

Safety at sea is increased with loran. In case of disaster, minimum time is lost in searching operations, if the loran position is included in the distress message.

Use being made of Loran

At the end of World War II loran receivers had been installed in approximately 3,000 surface craft and 30,000 aircraft of the military services. In addition, the U.S. Navy, U.S. Army, U.S. Coast Guard and the Royal Canadian Navy are now making use of direct-reading loran equipment like that illustrated in Fig. 1. The U.S. Coast Guard finds loran invaluable in keeping their weather ships on stations. The number of military ships and planes now equipped with loran cannot be disclosed. However, according to a report published by the U.S. Coast Guard, as of June 30, 1953, a total of 862 loran receivers were in use on commercial ships and planes. Of this number 445 were on ships of U.S. registry and 98 on ships sailing under the flags of the 13 nations previously mentioned. The 319 lorans on commercial overseas aircraft are being operated by 17 airlines, only seven of which are U.S. lines.

The ability to check up on the ship's position as frequently as desired makes it easier to sall great circle courses. Although loran was originally intended only as a long-range aid, more and more ships are finding it equally useful for coastal shipping, particularly along the East Coast of the United States. In this area over 80 tankers are finding that loran helps them take advantage of the savings in time and fuel possible by keeping their ships near the axis of maximum velocity of the Gulf Stream on northward passages between the Straits of Florida and Cape Hatteras (3).

Loran is being used extensively by fishermen on both the East and West Coasts of the United States. They find that loran helps them quickly locate and return to their favorite fishing banks. In addition, it helps them get their catch to market with the least delay. Records show that loran-equipped trawlers usually bring in the record catches.

A Mark I loran was installed in November 1949 in the Western Union cable ship *Cyrus Field*, of Canadian Registry. In the vicinity of the Bay of Fundy where this ship is frequently required to work, there is a great amount of fog. The Captain of this cable ship recently reported that, before they had loran, operations were often delayed in this area from ten days to two weeks for lack of celestial observations. With loran there is no delay as the ship can be brought to a point within one-half mile of the proper station at any time, and very often they can pick up the cable with the grapnel on the first attempt. It costs an estimated $2,000 a day to operate this ship. A ten day wait for clear weather would represent a loss of $20,000, which can be saved with loran.

The Sun Shipbuilding and Drydock Company, Chester, Pennsylvania, has made use of two standard marine lorans in connection with trial runs made off the Delaware coast of several super tankers recently completed. Loran readings on two different station rates were made simultaneously by two operators at 30-second intervals, a third man timing the operation from the sweep second hand of a clock. A plot of the time-difference readings against time shows that the readings fall on a straight curve with very little scattering from the mean.

(3) See *International Hydrographic Review*, Vol. XXIX, No. 2, Nov. 1952, page 93.

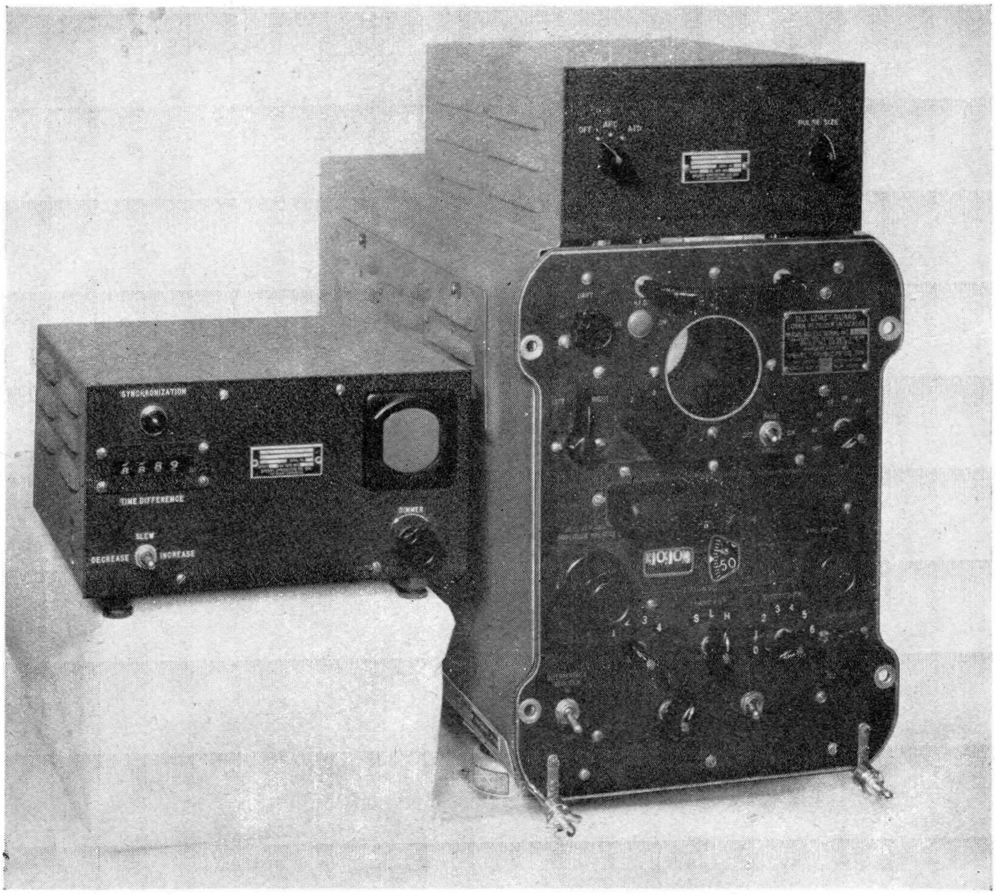

Fig. 10.

Sperry Marine Loran receiver-indicator modified for U.S. Coast Guard to be self-tracking and with reduced weight for use in aircraft. A pilots remote indicator, at left, repeats both the time difference and scope presentation on fastest sweep, and includes a light to indicate station blinking. Two of these equipments provide two lines of position simultaneously.

The advantage over the use of a measured mile is that with loran it is possible to make trial runs in deep water at any distance off shore desired.

Direct-reading loran receivers are now commonly found on commercial vessels of all sizes and types including large luxury liners, cargo vessels, tankers, fishing boats, ocean-going tugs and many private yachts.

Continuous-Indicating Loran

A recent development which holds considerable promise for future applications is a continuous-indicating or self-tracking loran receiver unit. Under a contract with the U.S. Coast Guard, the Sperry Gyroscope Company modified several Mark 2 marine loran equipments, as shown in Fig. 10, make them self-tracking.

The several extra tubes and other parts necessary to convert for this semi-automatic use were assembled on a small sub-chassis mounted on top of the standard receiver-indicator. To reduce the weight the cast-aluminum housing was replaced with a light sheet-metal case on rubber mounts, since the equipment was intended for use in aircraft.

With this special device the pulses must be selected and an approximate match made manually, as with the standard unit. Then when the operator switches to automatic time difference (ATD) the unit continues automatically to control the amplitudes of the two pulses and maintain a perfect match. Thus, without the operator touching any of the controls, the numbers automatically indicate the changing time difference as the craft on which the unit is installed moves over the surface of the earth.

With ground waves the self-tracking unit is capable of automatic operation under weak signal conditions when manual operation is almost impossible. The unit also can be used with sky waves, although more care is required and, for best accuracy, the operator must watch the scope and read the numbers when both signals are normal. By using two receiver equipments two lines of position are obtainable simultaneously.

A remote indicator was provided for installation in the pilot's compartment. This unit, shown at the left in Fig. 10, repeats both the time difference reading and the scope presentation on the fastest sweep. It also includes a synchronization light which goes out if two signals are not matched, or if station trouble blinking occurs.

The U.S. Coast Guard has reported that self-tracking loran receivers have been used successfully for several years in their ice patrol work. With this semi-automatic equipment much time can be saved, as the plane's position is known at all times and it is no longer necessary to circle icebergs while the navigator determines his position.

The Coast Guard made a further modification of the continuous-indicating marine lorans for use with an auxiliary device to record automatically the time difference. The record in microseconds is recorded by a pen on a rolled chart. An automatic-tracking receiver with recorder was used in both the builder's and the official trials of the super-liner SS *United States*.

The trial runs of the SS *United States* were made on the Hatteras-Nantucket 1H4 loran base line. By so doing the distance covered by the ship in nautical miles could be determined directly by multiplying the time in microseconds by 0.08086, as the miles per microsecond are constant on a loran base line.

The standard Mark 2 Mod. 2 marine equipment now available does not include this self-tracking feature. Under favorable conditions with the standard marine unit, an experienced operator can obtain two loran readings in approximately 60 seconds. It appears doubtful if a reduction in this time would warrant the additional cost of the self-tracking refinement for shipboard use. However, the self-tracking loran would be a distinct advantage for fast-moving aircraft, and the pioneer work sponsored by the Coast Guard proves that such equipment could be developed.

Self-tracking loran equipments are not yet commercially available for either ships or planes, as this special equipment is still in the developmental stage.