RECENT DEVELOPMENTS IN THE USE OF LORAN

Paper prepared by C.W. DAVIS (1) for presentation February 14, 1953 at Western Regional Meeting of Institute of Navigation, March Air Force Base, Riverside, California.

The electronic long-range navigational aid Loran was developed for our government to meet a military need during World War 2. Because of the great utility value of loran in time of peace, the Chief of Naval Operations has very wisely permitted the use of the system by private and commercial ships and planes. Loran has reached a state of maturity where many shipping and overseas air-transport companies now regard it as a necessary adjunct to their navigational equipment.

It is assumed that most of those present are familiar with how loran enables a navigator, by measuring the difference in time of arrival of two radio signals, to determine the geographical position of a ship, or plane, by crossing two or more hyperbolic lines of position. The purpose of this paper is not to describe the loran system but rather to review progress made, since the end of World War 2, in the use of loran, and to comment on some recent developments in receiving equipment, as well as on improvements made in transmitting facilities and cartography.

Improvements in Receiver-Indicators

Direct-reading marine loran receiver units were first developed for the U.S. Navy by the Sperry Gyroscope Company. They were first made available to merchant shipping in 1946. With such units as soon as a pulse match has been made the time difference in microseconds can be read directly from numbers on a Veeder Root type of counter. This feature eliminates the work of deriving the time difference from time markers on the scope — which procedure was charasteristic of all loran equipment used during the war. Good use is still being made of many of the war-surplus « pip-counting » lorans but they have now been relegated to the category of the automobile without a battery and self-starter.

Another feature included in the modern receiver-indicator which has greatly simplified the matching of the pulses is automatic frequency control, or AFC, which synchronizes the receiver timer oscillator frequency with that of the oscillator in the transmitter. AFC helps the operator to place the master station pulse at the proper position on the top trace and it then prevents this pulse from drifting. Without automatic control of the frequency it is necessary to make frequent adjustments of the oscillator frequency to keep the pulses in view. When homing on a loran line the AFC is capable of holding the master pulse in the center of the fast sweep indefinitely. Also, when a ship's course cuts across a family of loran lines the master pulse remains locked in place by the AFC and

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by turning two knobs a reading can be obtained in a few seconds to check the distance made good.

A further improvement in the Sperry Mark 2 loran receivers is a motor-operated, continuous, time delay. This is obtained by three cascaded selector channels and three phase-shifters geared together for operation from one shaft providing an uninterrupted delay continuously variable over the entire measuring range. This makes pulse matching a very simple and straightforward process, as movement of the bottom pedestal in steps is avoided.

Gulf Stream Investigation

Ever since the discovery of the Gulf Stream, navigators have been attempting to maneuver their ships into the center of this ocean current to save time and fuel. From the straits of Florida this stream proceeds northward and then curves to the northeast passing to the south of Cape Hatteras and Nantucket. An approximate location of this stream was first shown in 1770 on an Atlantic Chart by Benjamin Franklin. The position currently shown on charts is based on information provided more than 60 years ago by Commander J.E. Pillsbury, U.S.N., while in command of a Coast and Geodetic Survey vessel. Modern shipping requires a more exact delineation of the Gulf Stream.

New information on the behaviour and location of the Gulf Stream has been made available through a survey made with loran. Where loran coverage is available it is possible to get accurate fixes as frequently as desired. This survey was started at the suggestion of Capt. W.R. Griswold, Master of the Sperry Laboratory motor vessel *Wanderer*. A conference held in Washington early in 1950 included representatives of the Navy Hydrographic Office, the U.S. Coast and Geodetic Survey, and Sperry Gyroscope Company. It was then decided that the Hydrographic Office would establish a project to study the Gulf Stream in relation to the navigation of tankers. Five northbound tracks were specified, one the Pillsbury route and two on each side of this. Reports from the tankers participating in the survey consisted of logs giving hourly positions, course, dead-reckoning speed, shaft revolutions, sea temperature, and weather conditions. From May 1950 to May 1951 a sufficient number of reports had been submitted to permit the first analysis of the data. The results of this survey have been summarized on the back of several Sailing Charts.

The most efficient northbound route on a mean annual basis was found to be several miles to the west of the Pillsbury route. Time will not permit a discussion of the details of the findings, but it is of interest to note that ten oil companies already have installed loran receivers on a total of more than 80 tankers which operate along the coast of the United States. This is evidence that they are able to navigate more efficiently with loran than is possible with other means of navigation.

Continuous-Indicating Loran

An important development, with great promise of future applications, is a continuous-indicating or self-tracking loran receiver. The Coast Guard awarded Sperry a contract to modify several marine loran receivers to make them semi-automatic. The several extra tubes and parts necessary to convert the standard

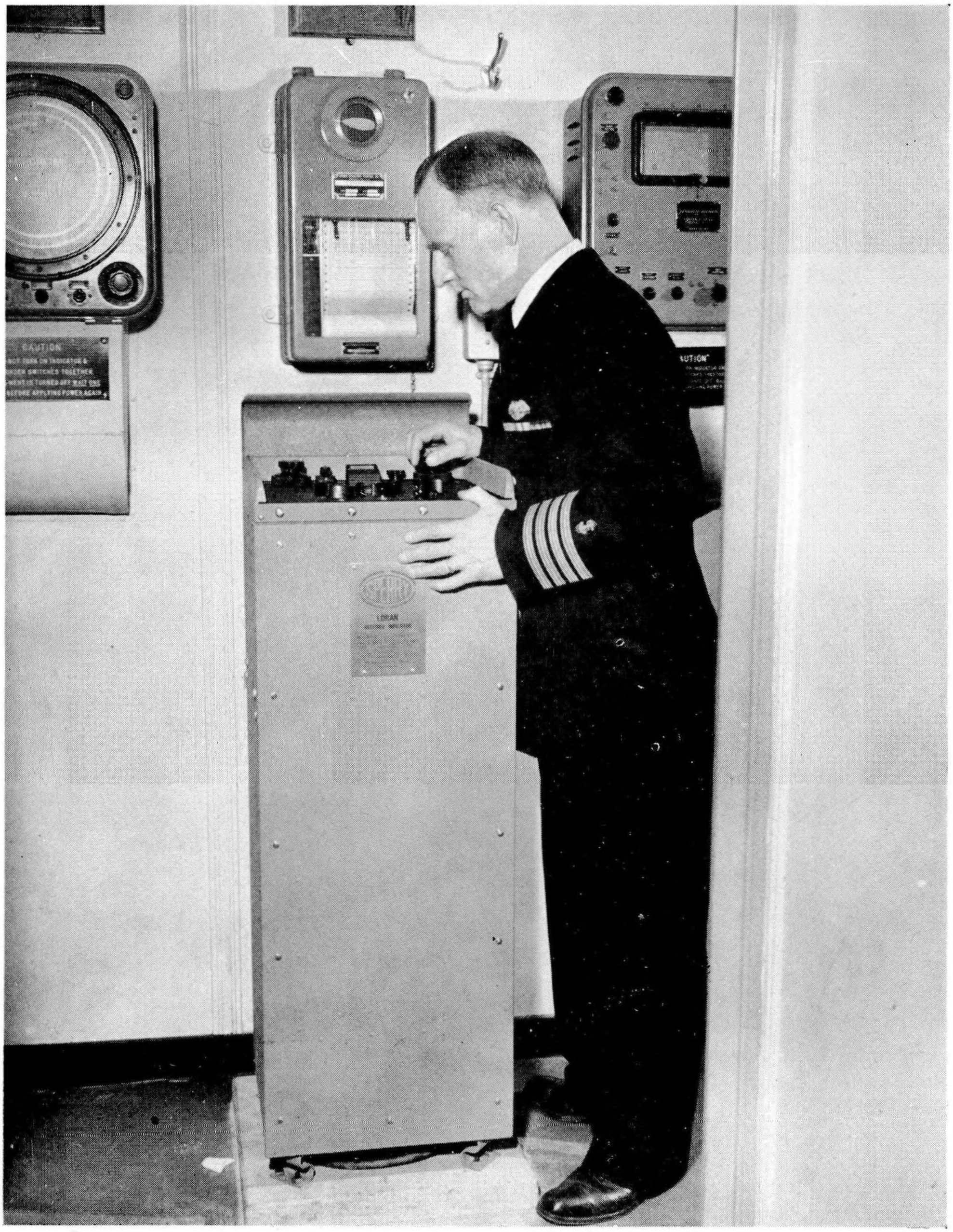

Fig. 1. — This Mark 1 Mod. 1 marine loran receiver is typical of the first direct-reading loran produced.
It was developed for the U.S. Navy by Sperry Gyroscope Company.

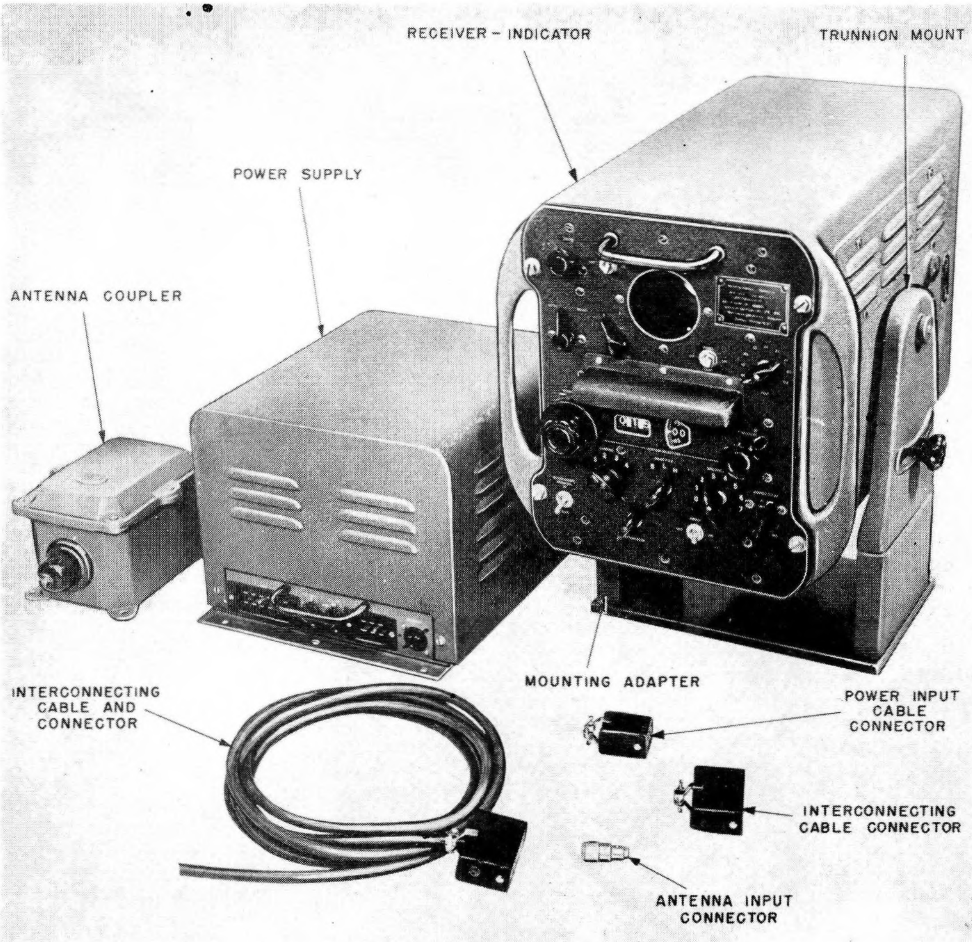

Fig. 2. — Components of current model of Sperry Mark 2 Mod. 2, direct-reading, marine loran receiving equipment.

Fig. 3. — Trunnion mounting makes the marine loran suitable for table or bulkhead mounting.

Fig. 4. — The loran receiver-indicator may be bolted to a cast-aluminium pedestal for deck mounting.

Fig. 5. — Control panel of Sperry direct-reading loran features :
(1) Black-lighted, time-difference indicator,
(2) Automatic control of timed frequency,
(3) Motor dirven, continuous, time delay, and
(4) Self-contained test circuit.

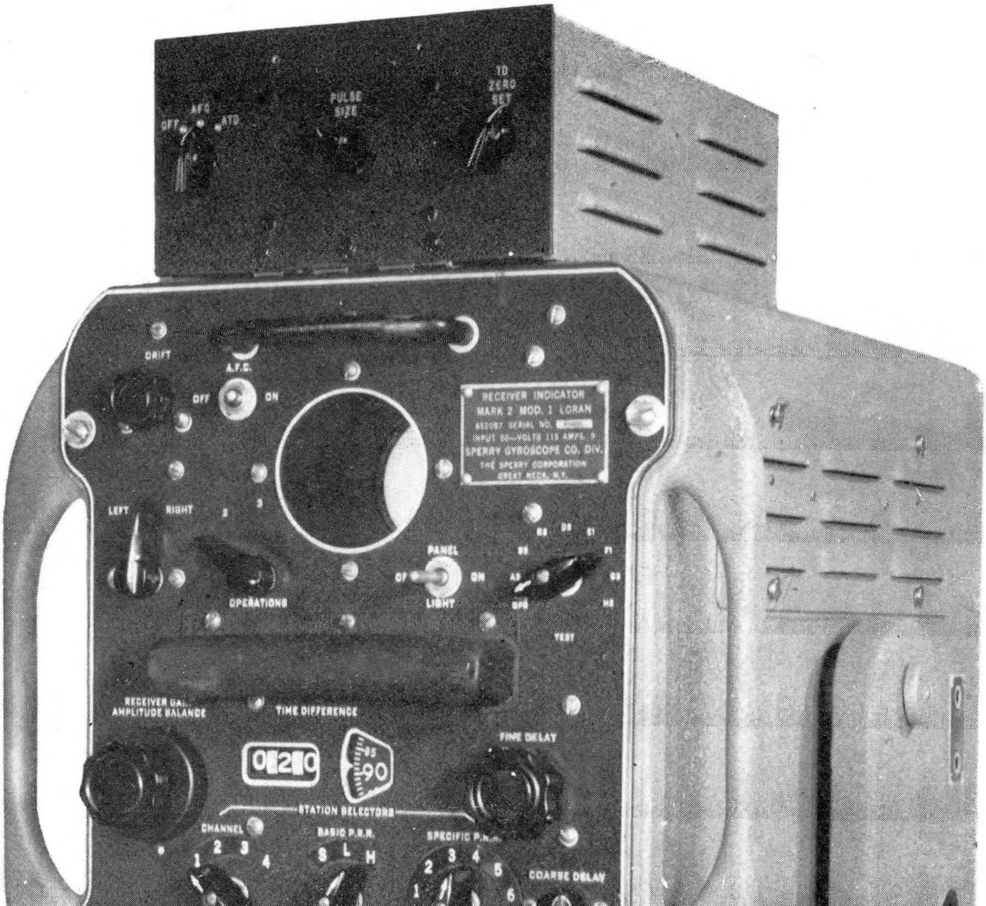

Fig. 6. — Sperry marine loran receiver modified for self tracking operation.
After signals have been matched manually and
when selector switch is thrown to AUTOMATIC TIME DIFFERENCE
the numbers of the time-difference indicator change automatically as the ship moves.

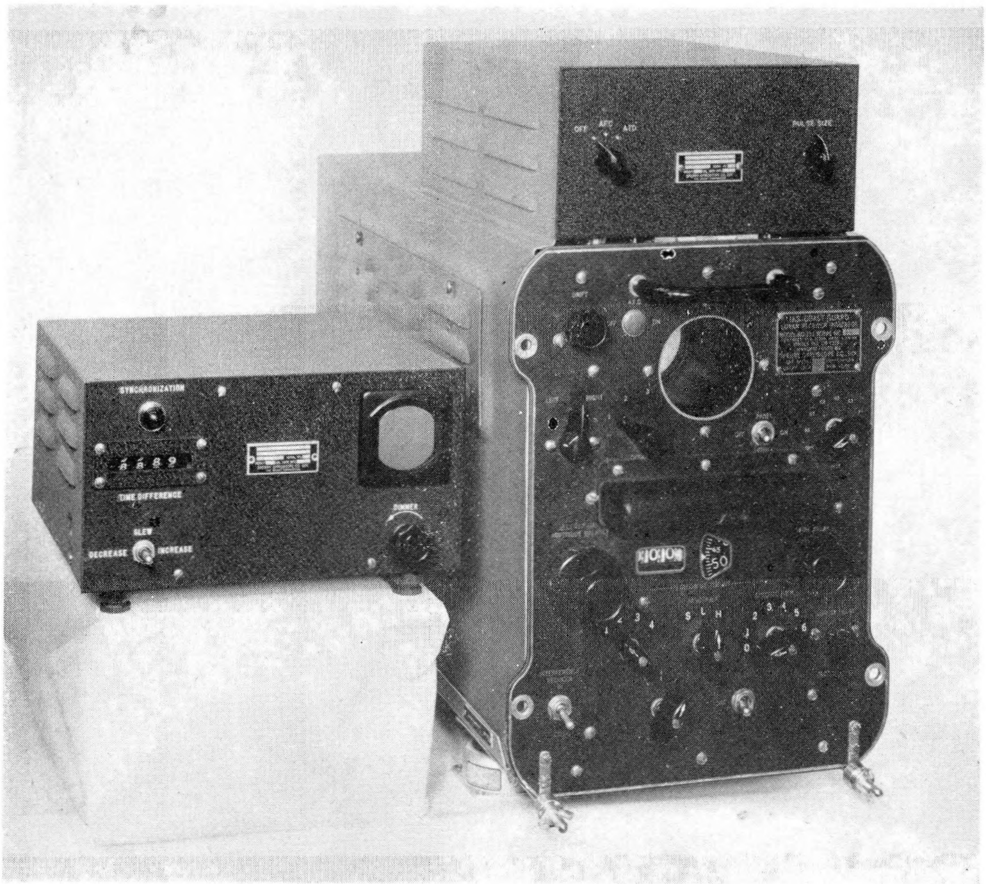

Fig. 7. — Sperry marine loran receiver-indicator modified
for U.S. Coast Guard to be self-tracking
and with reduced weight for use in aircraft.
A pilote remote indicator, at left, repeats both the time difference
and scope presentation on fastest sweep,
and includes a light to indicate station blinking.
Two of these equipments provide: two lines of position simultaneously.

receiver-indicator to a self-tracking unit were assembled on a small sub-chassis mounted on top of the standard receiver unit.

With this semi-automatic device the pulses must be selected and matched manually, as with any direct-reading loran. Then the navigator switches over to automatic and the unit continues to control the amplitudes of the two signals and maintain a perfect match. The numbers on the time difference indicator then automatically change as the receiver moves over the surface of the earth.

The Sperry Mark 2 Mod. 2 standard marine loran receiver does not include this self-tracking feature which is still in the developmental stage and not yet commercially available for either ships or planes.

Self-tracking Lorans Used for Ice Patrol

The Coast Guard has reported that self-tracking marine loran receivers have been used with good results in aircraft for the past three years for International Ice Patrol work. In this case two receivers were used. An automatic receiver was set up on the most rapidly changing loran line of position and the other, a standard airborne receiver, was operated on another more slowly changing loran rate. With this system much time could be saved as the plane's position was known at all times. Thus it was no longer necessary to circle icebergs while the navigator established his position. It was found that the continuous-indicating loran receiver was capable of automatic operation under weak signal conditions when manual operation was almost impossible. Skywaves are usable but more care is required and the navigator must watch the scope and read the numbers when both signals are normal.

Self-tracking Loran for Aircraft

The Coast Guard has taken a further step forward and are having additional marine direct-reading loran receivers modified for use in aircraft to reduce the weight and provide two loran lines of position simultaneously. These dual equipments will include remote time-difference indicators for installation in the plane's cockpit. The modified receiver-indicators will include a number of circuit improvements over the units first modified for marine use.

A light-weight self-tracking loran which would provide two lines of position simultaneoulsy would be particularly desirable for fast-moving aircraft. The pioneer work sponsored by the Coast Guard proves that such equipment could be developed.

Automatic Recording Loran used for Trial Run of SS United States

The Coast Guard made a further modification of their continuous-tracking marine loran receivers to make them automatically record the time difference. The record in microseconds is recorded by a pen on a moving tape. An automatic tracking receiver plus recorder was used in both the builders and the official trials of the super-liner *SS United States,* this special loran equipment being loaned by the Coast Guard.

It is of interest to note that 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 vessel in nautical miles could be determined directly by multiplying the change in microseconds by 0.08086, as the number of miles per microsecond is constant on a loran base line.

Speed Trial of SS Delaware Sun

Two standard marine direct-reading loran receiver-indicators were recently used by the Sun Shipbuilding and Drydock Company on the trial run of the new 30,000-ton tanker, *SS Delaware Sun*. After sailing down the Delaware River, from Overfalls lightship the tanker was set on a course of 123 degrees with Gyro-Pilot to parallel a 1H4 loran line and this course was maintained until reaching a point beyond the 30-fathom curve, which is about 60 miles off shore.

The actual speed runs were then made on courses of 203 and 23 degrees which parallel the 1H0 lines and very nearly cross at right angles the 1H4 lines which in that area are accurate to about 0.084 miles per microsecond. During each of the four speed runs, each of which were of 15 minutes duration, engine revolutions and two loran readings were made simultaneously on two loran units by two operators at 30 second intervals, with a third man timing the operation from the sweep-second hand of a clock. At the end of each of the runs the ship was given 5 degrees right rudder to bring it out on the new course with no change in engine revolutions.

By plotting the time difference readings against time it was found that the readings fell on a straight curve with very little scattering from the mean. This trial shows that by proper use of standard loran equipment ship time trials may be made off shore in deep water with satisfactory results.

Improvements in Charting

The Hydrographic Office is continuing the practice of issuing loran tables for the new station rates and is keeping the N, NW, VL, and VRL series of charts revised as the station rates are changed.

A major rôle in extending the use of loran tables, particularly in coastal waters, has been the improvements made in loran charts issued by the U.S. Coast and Geodetic Survey. Until recently the only loran charts available were those issued by the Hydrographic Office. Most of these have not included other information of interest to the mariner, and normal procedure was to obtain a fix from the intersection of two or more lines on a loran chart and then to transfer this position to a navigational chart.

The U.S. Coast and Geodetic Survey has begun the practice of placing loran lines on a number of their sailing, coastal, and harbor-approach charts. On the back of several of the smaller-scale sailing charts the same chart appears with loran lines added. On the more recently issued, larger-scale charts a different practice has been followed of including on the standard navigational chart loran lines as well as all other information such as compass roses, lights, buoys, radio beacons, type of bottom, danger areas, fathom curves, and soundings in shallow water. With these new charts the navigator can obtain a fix with loran directly from the navigational chart and it is no longer necessary to work with two charts.

Several things have been done to keep the loran lines from obscuring the other information on the chart. Lighter colors and much narrower lines have been used for the loran lines than has been the practice on the Hydrographic charts. On the new Coast and Geodetic Survey loran charts, instead of maintaining a uniform interval of 20 microseconds (the former practice on marine charts) various microsecond intervals have been used such as 100, 50, 20, 10 and 5 microseconds, depending on the spacing of the lines and scale of the chart — but in no case is the spacing less than about one-half inch.

In advancing the science of navigation the addition of loran lines to standard navigational charts marks a milestone of progress for the mariner.

Improvements in Transmitter Facilities

To the Coast Guard is due the credit for relocating and improving many of the transmitting stations since the end of World War 2 to better serve the peace-time needs of the navigator. The power of many of the transmitters has been increased from about 100 kw to 1000 kw. This has been done in the case of the transmitters in the Aleutians, those on the east coast of the United States, as well as at Bona Vista, Newfoundland and at Battle Harbor, Labrador. This increase in power has extended the useful ground-wave range over water to 900 miles, or more, and has improved the ratio of signal to noise in coastal areas. The useful range at night is still limited to 1400 miles.

The three stations in the Aleutians were relocated in 1950, and three new stations began operation in the Gulf of Alaska in March 1952. In November 1952 the three former stations in the Hawaiian Islands were replaced by four new stations.

Loran coverage for the approaches to New York has been greatly improved by the addition of a new station at Sandy Hook. Three new loran stations in the eastern part of the Gulf of Mexico were placed in operation in September 1951. These are operated by the U.S. Air Force, whereas other American stations are operated by the Coast Guard. The stations in the Gulf of Mexico are proving especially useful for tanker fleets which operate between Gulf and various Atlantic ports.

It has been reported that the Coast Guard contemplates placing in service in the near future some improved timers which are expected to effect a considerable improvement in station synchronization. On most stations, synchronization at present is being maintained within a tolerance of plus or minus two microseconds.

Need for Better Coverage in South Pacific

As with any hyperbolic system of navigation the accuracy is best on the perpendicular bisector of the base line and deteriorates near the extensions of the base line. The irregular contour of the Atlantic Coast permits locating the stations so as to provide somewhat better coverage near the coast than has been possible on the West Coast of the United States. South of Cape Blanco (in Oregon) the West Coast of the United States is convex — that is, the coast line bulges out into the ocean. Where loran stations must be located on such a coast line, the service area containing good crossing angles is reduced, and a further

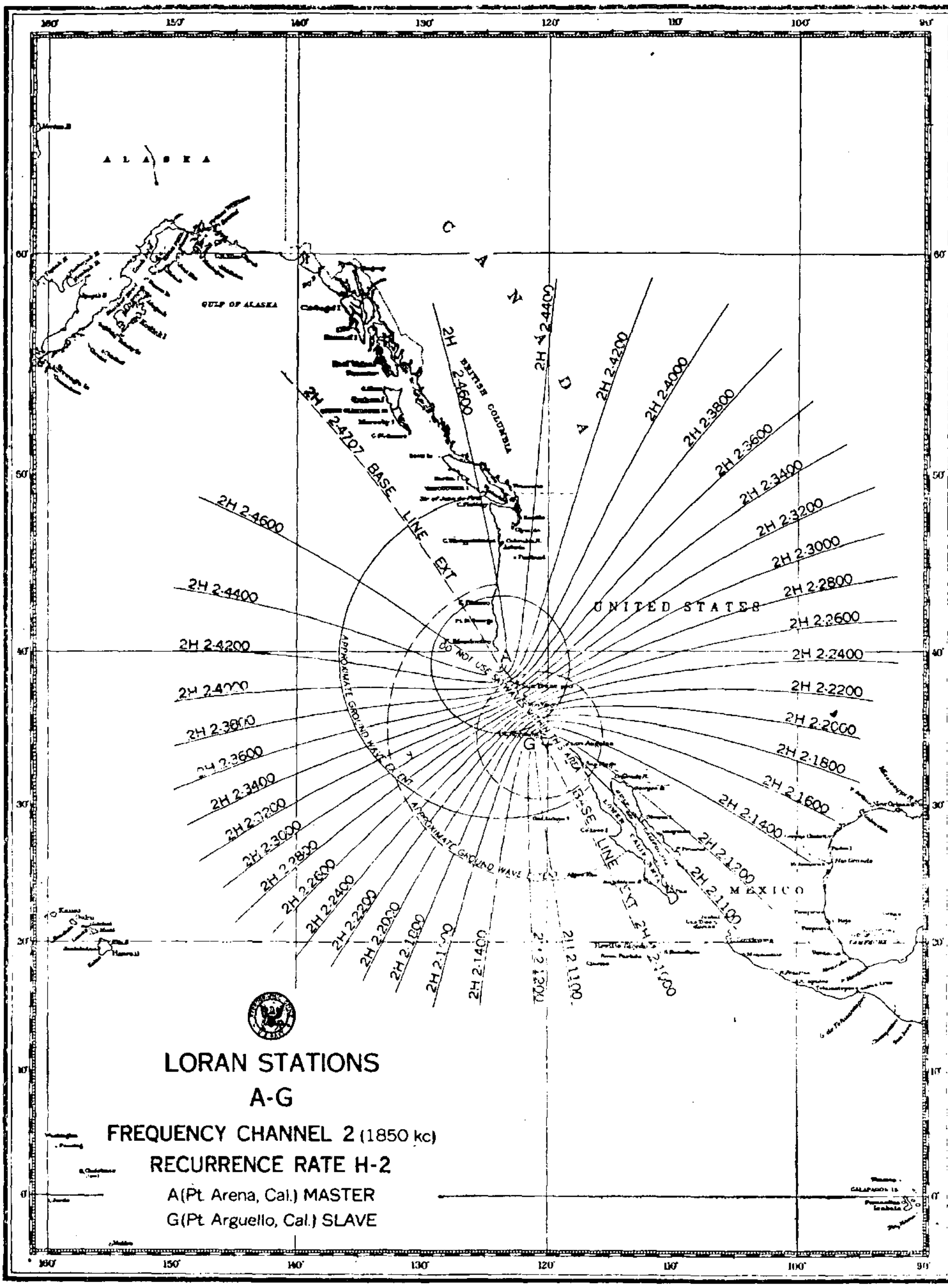

Fig. 8. — Because of convex coast line the 2H2 loran slave base-line extension is near lower California, resulting in poor accuracy in this coastal area.

disadvantage is that the base-line extensions fall in coastal waters where ships travel up and down the coast. Due to proximity to base-line extensions the loran coverage is especially poor south of Point Arguello (in California) and in the coastal area off lower California. Coastal shipping and fishing boats in particular could make good use of loran if coverage could be provided south from Point Arguello to the Panama Canal and as far west as the Galapagos Islands.

If arrangements could be made with the Mexican Government to place a loran station on the Island of Guadelupe it could be tied in with the existing station at Point Arguello, as well as with another new station which might be located in Lower California near Cape San Lazaro. These two additional stations would provide two more station rates which would go a long way toward providing service needed by commercial shipping.

The Coast Guard is no doubt aware of the lack of coverage in this part of the South Pacific. However, because military considerations must take precedence, nothing is likely to be done to extend the loran coverage into this area unless commercial shipping companies and fishermen make their needs known by writing to the Commandant of the U.S. Coast Guard, at the Coast Guard Headquarters in Washington, D.C.

At present there are in operation in the Atlantic and Gulf of Mexico a total of 17 loran stations and in the Pacific 32 loran stations. It is apparent that our government is spending more money to provide loran service in the Pacific than in the Atlantic. The records of the number of loran-equipped commercial ships indicate that the use being made of loran in the Pacific by passenger, cargo, tanker, and fishing vessels is negligible compared to the number of ships using loran in the Atlantic. It appears that ship owners on the West Coast are not taking advantage of the loran coverage available in the Pacific. It is hoped that the comments made in this paper will help to stimulate a further extension of the use of loran in the Pacific.