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SHORAN FOR HYDROGRAPHIC SURVEYS

OPERATIONAL TESTS CONDUCTED BY THE
U. S. COAST AND GEODETIC SURVEY
1945

by

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U. S. C. and G. S. Ship EXPLORER
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S H O R A N

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HOW SHORAN WORKS

SHORAN is the name given to a type of RADAR system which gives very accurate determination of position. The name is made up of the initial letters of SHORT RANGE NAVIGATION. The equipment was designed for the particular purpose of bombing control by airplane; it is a development of the Radio Corporation of America. Since its accuracy is so great, this equipment has been used for other types of control such as air-photography, reconnaissance, and so on. Its application to actual ground surveys has not been thoroughly investigated, but the use of this equipment for hydrographic survey control has been tested during this year with excellent results.

SHORAN equipment was developed for installation in aircraft, or to be transported by aircraft. Hence, the size and weight of the equipment has been kept at a minimum; and the power requirements have been based upon the usual power types available in the modern aircraft. The equipment is actually a very precise Interrogator and Transponder system. Therefore it consists of two main units (in principle): the interrogator which is air-borne, and the transponder which is on the ground. These are usually referred to as the Ship and Ground Stations, respectively, and will be so designated in this discussion.

The SHIP STATION consists of two units: an Indicator which measures the time elapsed between a transmitted pulse and the returned signal; and a Transmitter which is keyed by the Indicator and sends out the signal to the GROUND STATION. The Power supply must be added, as well as the antenna and connecting cables, and other accessories to make the installation complete.

The GROUND STATION also consists of two units: a Monitor which receives the signal from the Ship Station, and retransmits it back through the Transmitter. This equipment must be supplemented by the antenna system, power supply units, and so on. Hence, the distance measured at the Ship Station will be the loop distance, which is, of course, twice the desired distance. If there are two Ground Stations used in conjunction with a Ship Station, two distances will be measured at a particular instant. If the positions of these two Ground Stations are accurately known and plotted, the position of the SHIP can be ascertained by the intersection of the two arc-distances from their respective stations. A 'block diagram' of the Ship and Ground Stations is shown in Fig. 1.

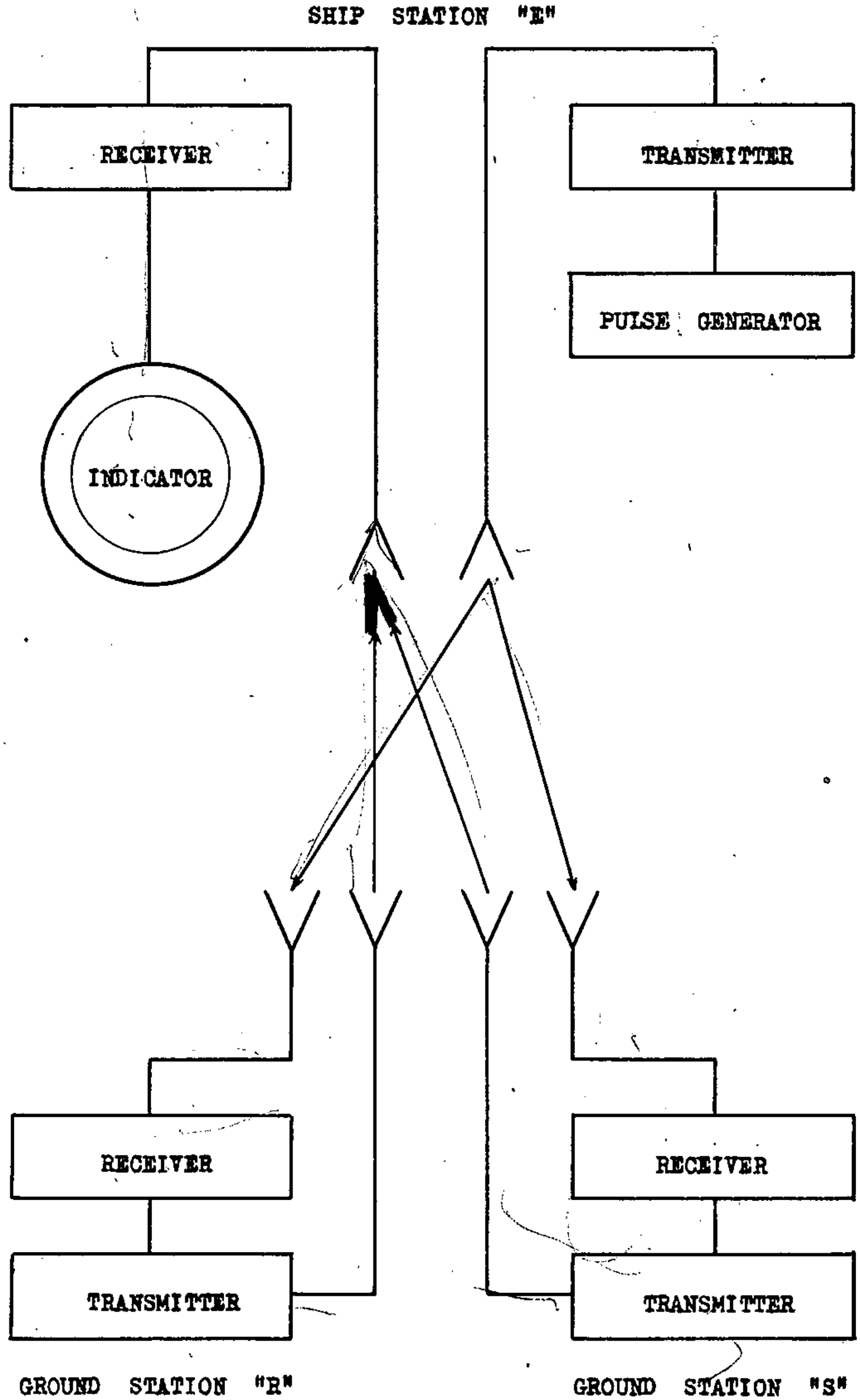


FIGURE 1.
BLOCK DIAGRAM OF SHORAN SYSTEM.

THE SHIP STATION.

The SHIP STATION has been given the designation AN/APN-3, which means: Army Navy Airborne Radar Navigation Equipment Type 3. As stated above, this equipment consists of two main units plus their accessories. These are the INDICATOR (ID-17/APN-3), which includes a RECEIVER (R-15/APN-3); and the TRANSMITTER (T-11/APN-3). The accessories include the antenna dipoles, the transmission lines and connecting cables, and the power-supply sources. Other accessories available for use with the Indicator, are a COMPUTER and a PILOT'S DIRECTION INDICATOR (PDI) System. These are not installed during the operations on board the Ship EXPLORER, and will not be generally used, so will receive no further attention.

Radio Set AN/APN-3 fixes the position of the ship by indicating to the operator the 'straight line' distances to the two Ground Stations simultaneously. A line sketch of this operation is shown in Fig. 2 which may be considered as a map view of the area in question. The two GROUND STATIONS are at points "R" and "S" and the SHIP at "E". The Indicator measures the distance 'r' which places the Ship on arc 'xx', and the distance 's' which places the Ship on arc 'yy'. The intersection of the two arcs will be the position of the Ship "E" since it is the only point common to both the 'xx' and 'yy' arcs. This type of graphical solution of the position problem is used, in principle at least, in all navigation either by plane or by ship. It will be noted by an examination of Fig. 3, that there are two positions possible for each pair of SHORAN Distances. A single pair will NOT determine a position without the knowledge of the general area in which one may find himself. The true direction of the Ship's heading will determine the direction from either point plotted. If the second pair of distances falls on this course line, the assumed position is correct; if not, the other position will probably be the correct one. A third pair of distances will be the desired check. It can easily be seen, that if the course steered is in a southeasterly direction, that only points 'A', 'B', and 'C' will plot on this course; and that points 'a', 'b', and 'c' are obviously not the true positions.

The SHORAN system measures the distances from the Ship to the two Ground Stations by measuring the time required for the radio signals to travel the distances from the Ship to these Stations and back to the Ship. If the elapsed time is known, then the distance can easily be computed. Or, better yet, if the time is converted to distance on the measuring element, then the distances may be read directly off this device. For the purpose of calibration of this equipment, the velocity of the electromagnetic wave through air (at standard barometric pressure of 29.92 inches Hg) has been taken as 186,218 statute miles per second; or, since the equipment actually measures the round-trip time between the Ship and the Ground Station, this velocity may be taken as

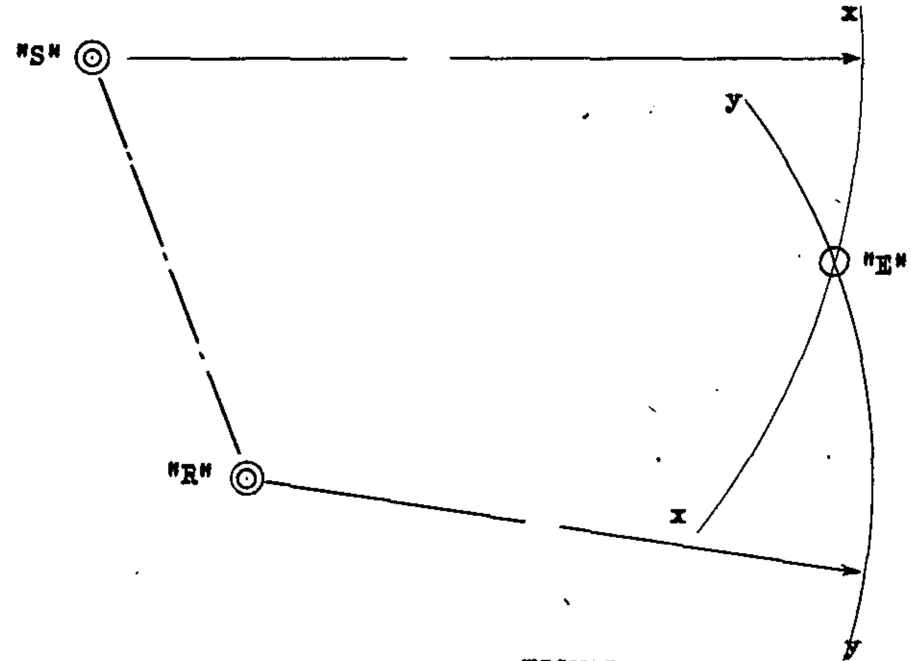


FIGURE 2.
POSITION BY SHORAN.

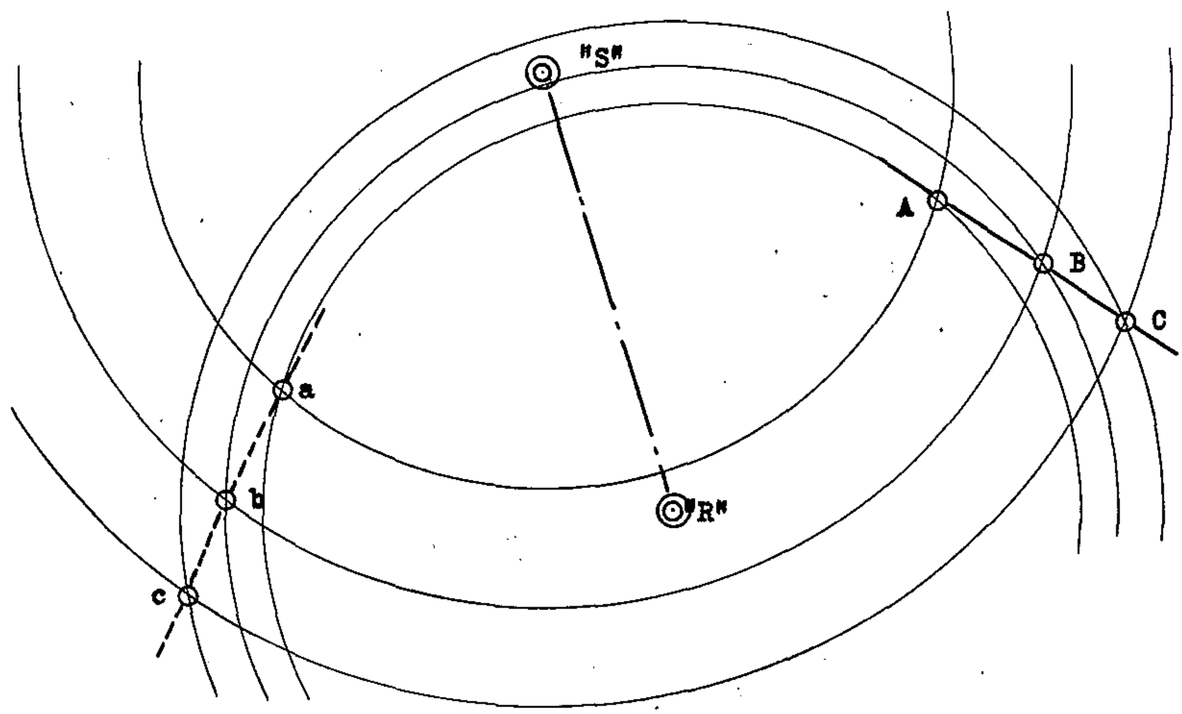


FIGURE 3.
AMBIGUITY OF POSITION
Solved by knowing true course.

93,109 statute miles per second for the total elapsed time. Hence,

$$D = Vt = \frac{186,218\ t}{2} = 93,109\ t, \text{ where}$$

D = distance in statute miles, and
t = time in seconds.

Since this relationship is very constant, even taking into account the effects of changes in barometric pressure, humidity, and so on, it is possible to calibrate the measuring device directly into miles and fractions (or, in this case: decimals). The velocity of the electromagnetic waves actually varies over a range of about 54 statute miles per second, from the minimum of 186,218 miles per second at a barometric pressure of 29.92 inches to a maximum of 186,274 miles per second in vacuo. The variation of velocity near the earth's surface, and under the ordinary variations of barometric pressure encountered will probably not exceed 1-mile per second, or even 2 miles at the most, which will give an error of about 1:100,000 if neglected.

As indicated in an earlier paragraph, the basic radio equipment used to create round-trip signal paths originating and terminating in the Ship Station is shown in Fig. 1. This basic equipment consists of a signal source (pulse generator), a Transmitter, and a Receiver installed in the Ship; and a Receiver and a Transmitter at each Ground Station.

Pulse signals originating at the Ship are radiated from the ship transmitting antenna (dipole) and received by one of the Ground Stations. There, the pulse is sent through the Receiver to the input of the Transmitter, and then re-transmitted back to the Ship. At the Ship, this pulse is passed through the Receiver and then routed to an indicating circuit in which its time lag, or loss, with respect to the original outgoing pulse may be measured in a way to be described later. This time lag is indicated directly in terms of statute miles to the Ground Station rather than in terms of time.

Since two distances are necessary to fix the position of the Ship, it will be seen that signal pulses must be sent to each of the two Ground Stations and these must be separated within the Indicator so that each distance is correctly shown. This is accomplished by sending out pulse signals from the Ship Transmitter on two different frequencies, a separate frequency to each Ground Station, so that the Ground Stations receive the signal pulses alternately, each on its own frequency, at a rate of about ten times per second. The Ground Stations then re-transmit to the Ship Station on the SAME frequency. Thus, the equipment provides, simultaneously (as far as the eye can detect), indications of the distances of the Ship from the two Ground Stations.

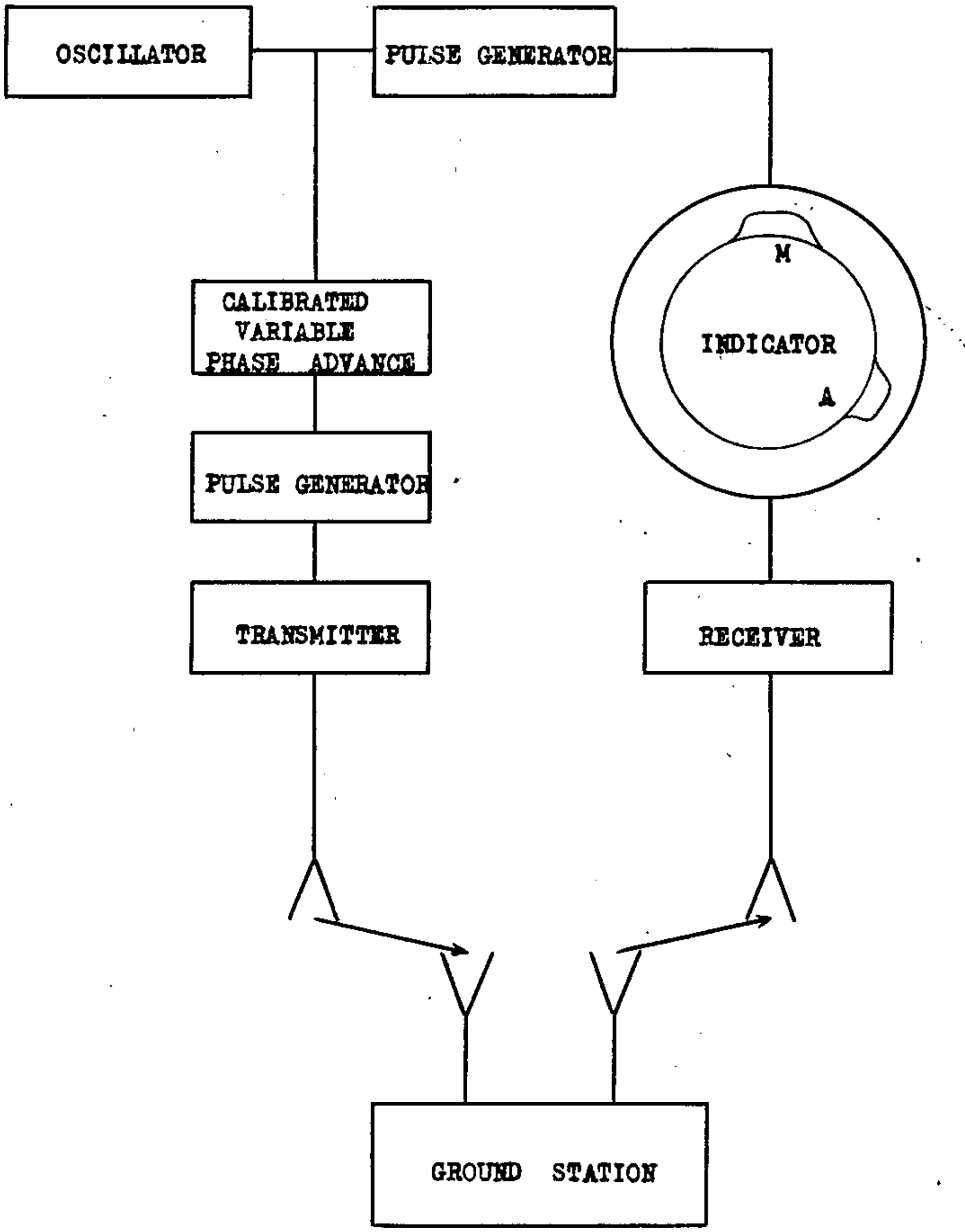


FIGURE 4.

BLOCK DIAGRAM OF SHIP STATION EQUIPMENT.

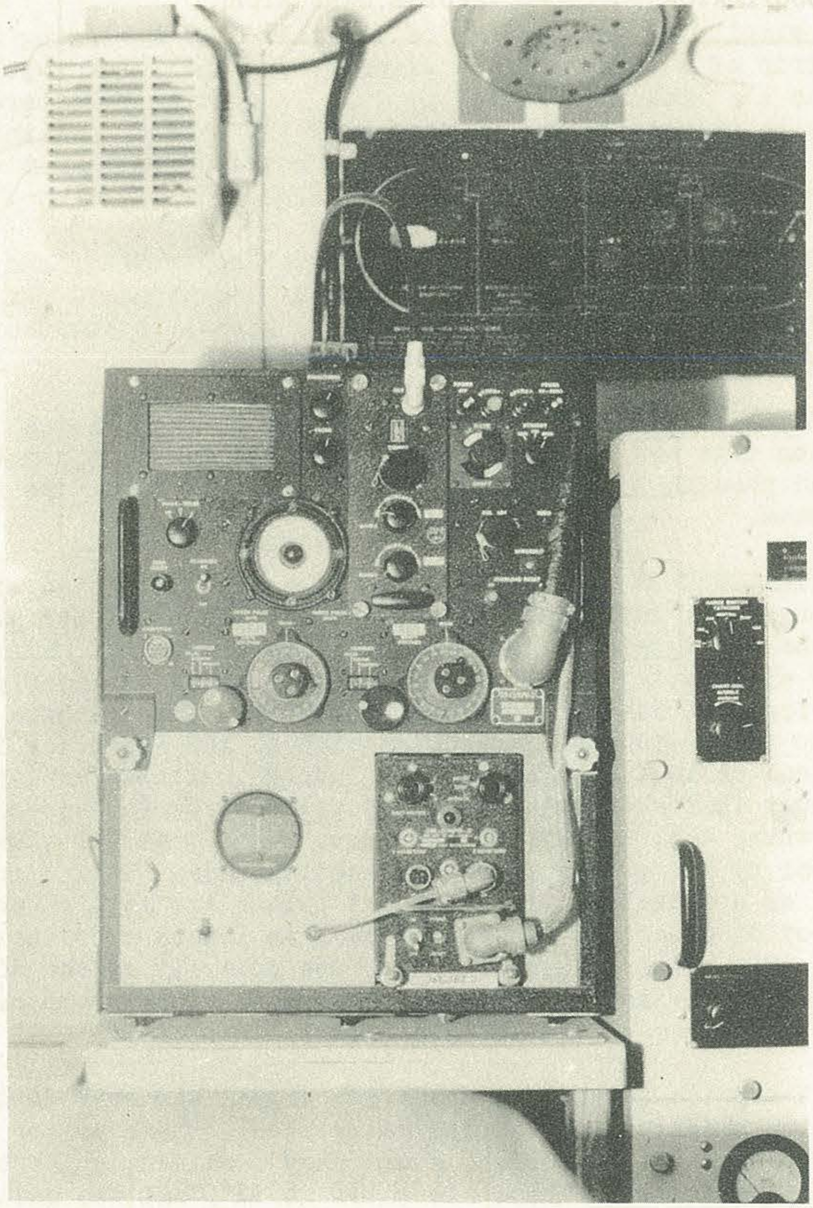


FIGURE 5.

THE INDICATOR - SHIP EQUIPMENT

THE INDICATOR.

The Block diagram of the Indicator (code name ID-17/APN-3) is shown in Figure 6.

A very simplified explanation of the method of measuring the time of a round-trip of a pulse will be given here. This discussion will be based upon the Sketch in Figure 6; but, it must be remembered, that this is only to illustrate the principle of the system, and therefore will differ in important respects from the actual arrangement used. A photograph of the Indicator is shown in Figure 5.

The OSCILLATOR in this diagram is crystal controlled, and of a very great frequency stability, and serves as the standard for timing intervals, since if the frequency of an A.C. signal is constant, the time between successive wave tops is constant.

The PULSE GENERATORS shown produce trains of short signal pulses, the repetition rate and relative timing of which are determined by the frequency and phasing of the standard timing signal (from the OSCILLATOR) applied to them.

The INDICATOR TUBE is a cathode ray oscilloscope fitted with an electrode for radial deflection in addition to the usual two pairs of plates for the electrostatic deflection in the horizontal and vertical planes. Two alternating voltages differing in phase by exactly 90° are derived from the Standard OSCILLATOR output. One of these voltages is applied to the horizontal deflection plates, and the other is applied to the vertical deflection plates, both through suitable amplifiers, with the result that a circular sweep is produced on the screen of the cathode ray tube, the velocity of the sweep being (nearly) constant, and determined by the particular scale setting used. This circular sweep serves as a time-base line. Signal pulses are applied to the radial deflection electrode and will appear as inward or outward deflections on this circle, depending upon the polarity of the signal voltage applied. Further, the disturbances will closely approximate in shape the wave form of the applied signal.

One of the pulse generators sends its signal directly to the radial deflection electrode of the Indicator Tube. These pulses appear at a fixed position on the screen, since they remained synchronized with the sweep generator. These are shown at "M", and are called the MARKER PULSES (since they are fixed in position). The other pulse generator keys the Transmitter. Pulses which have completed a round-trip to a Ground Station and have been received and amplified in the Ship RECEIVER are sent to the radial deflection electrode of the Indicator Tube, and appear as the Pulse "A" on the screen of this tube.

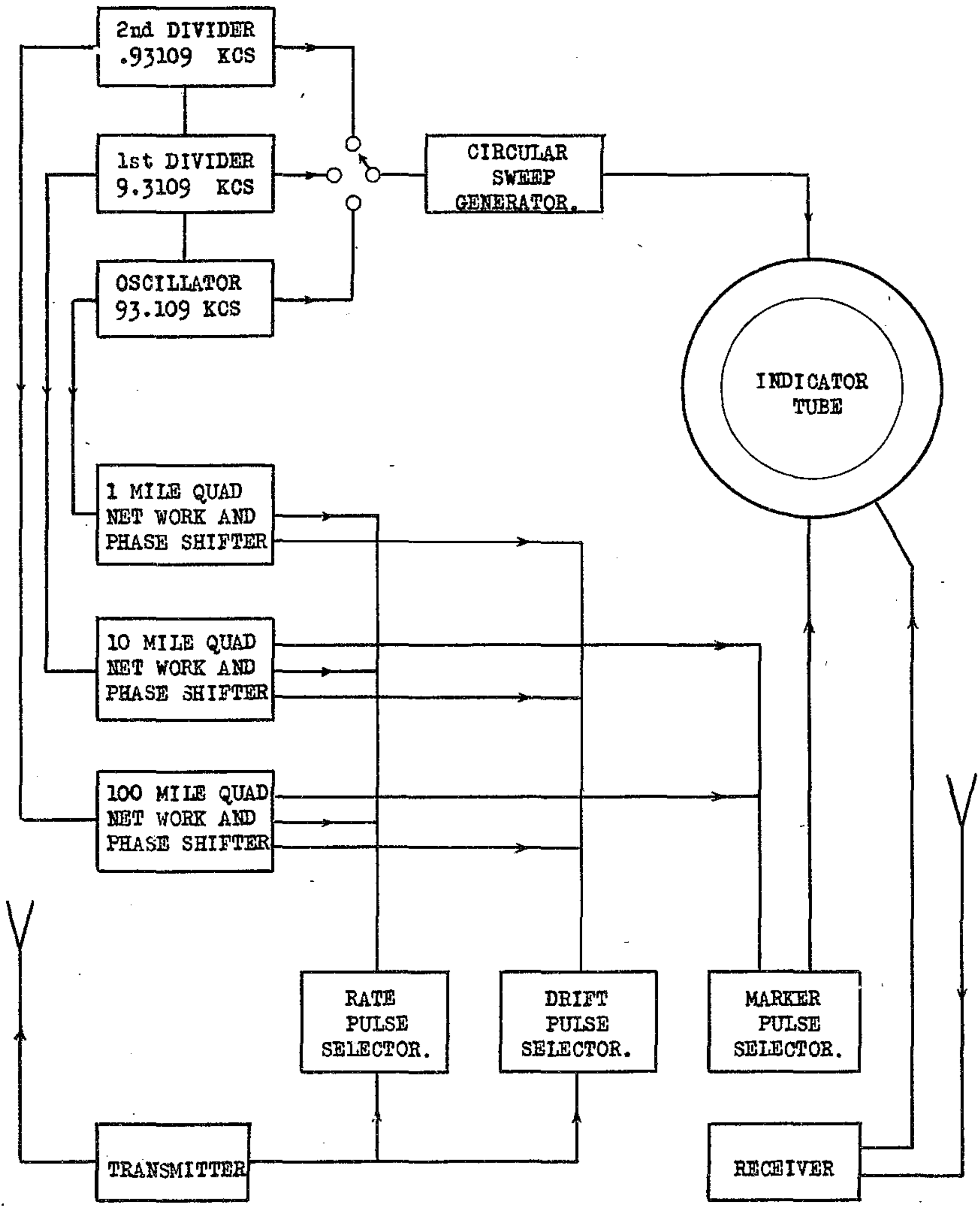


FIGURE 6.
SIMPLIFIED BLOCK DIAGRAM OF THE INDICATOR.

If the circuits of the Pulse Generators were so arranged that they produce their pulses simultaneously, a Marker Pulse "M" would arrive at the Indicator tube somewhat earlier than the corresponding pulse "A". This is true because the Marker Pulse needs travel over only a short length of wire in the Ship Equipment, while the other pulse must travel from the ship to the Ground Station and back, and in addition, it is further delayed by going through the circuits in the Ground and Ship Station Receivers and Transmitters. Therefore, in such cases, the Pulse "A" will appear at a different place on the sweep pattern on the Indicator Tube than the Marker Pulse "M".

The distance between the two pulses on the screen is the distance which the cathode ray spot has traveled during the time elapsed between the arrival of the Marker Pulse "M" at the radial deflection electrode, and the arrival of the pulse "A". A certain fraction of the distance indicated on the screen is due to the delays mentioned above, but the larger part of this distance corresponds to the time lost by the pulse "A" in travelling the round-trip radio path to the Ground Station. Therefore, the distance between the two pulses may be used as an indication of the distance from the Ship to the Ground Station. Since the error due to the time delays in the various components of the equipment can be measured, and can be considered as constant for any particular combination (of Receiver, Indicator, Transmitter on the Ship, or Monitor, Receiver and Transmitter at the Ground Station), this value may be subtracted from the total measured time interval, and the true round-trip time interval can be known.

Instead of using directly the distance between the pulses "M" and "A" on the Indicator Tube screen as a measure of the distance between the Ship and the Ground Station, a much more accurate method is used. Stated as simply as possible, it consists of producing transmitted pulses sufficiently earlier than the corresponding Marker Pulse "M" so that the returning re-transmitted pulses arrive just in time to meet their corresponding Marker Pulses "M" at the Indicator Tube. This advance timing of the transmitted pulses is obtained through a phase-shifting device (Goniometer) which advances the phase of the sinusoidal signal fed to the generator of the transmitted pulses.

This phase advancing is accomplished in the circuit labeled CALIBRATED VARIABLE PHASE ADVANCE. During navigation, the operator adjusts this device until the Pulse "A" on the Indicator Tube screen just coincides with the Marker Pulse "M". He then reads directly on the scale and vernier the distance in statute miles from the particular Ground Station. Naturally as the Ship gets further away from the Ground Station, this phase advance must be made greater in order to send out a transmitted pulse sufficiently early so that its returned signal will arrive to coincide with the Marker Pulse. Since the pulses are sent out at a repetition rate of about 930 per second (931.09 per second, to be exact), a 360° advance will correspond to exactly 100 statute miles (round trip of 200 miles). Thus, as the phase advance is increased to 360°, the timing of the transmitted pulse has been advanced by the time interval between two transmitted pulses. Then, the 360° advance is equivalent to a ZERO degree advance, and any further advance, say to 365° will correspond exactly to a 005° advance. Therefore, the scale indication for an actual distance of (say) 125 miles is exactly the same as for 25 miles, as the mileage repeats every one hundred miles. Hence, it is necessary to know approximately the Ship's position with respect to the Ground Stations in order to fix its position.

In order to take into account and correct for the delays inherent in the Ship and Ground Station equipments, they are computed taking into consideration the lengths of the connecting cables and the transmission lines, and then set these into the Ship Indicator as an "Off-scale"correction. The Ground Station equipment has been manufactured with a known delay which corresponds to 0.180 statute miles (of which more later). The delay in the Ship equipment is computed from the formula

$$E = \frac{1}{5280} \times \frac{1}{2} \times \left(\frac{R+T}{0.65} + \frac{I-i}{0.50} \right), \text{ where}$$

E = the error (additional delay) in the Ship Equipment;
R = the length of the Receiver Transmission Line in feet;
T = the length of the Transmitter Transmission line in feet;
I = the length of the Interconnecting Cable in feet;
i = the length of the Interconnecting Cable (test) in feet.

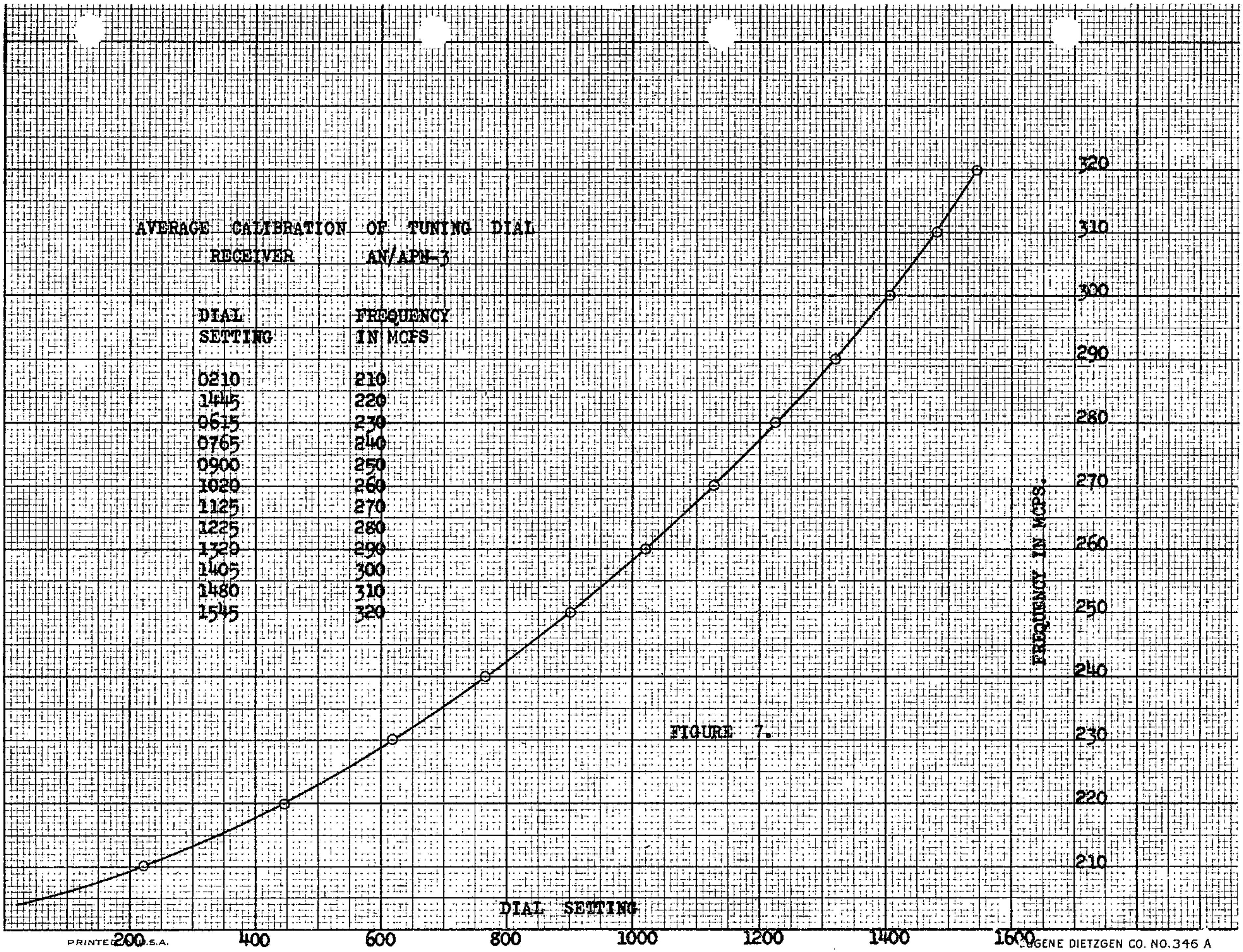
The exact procedure for setting up this delay is given in the Maintenance Manual and must be followed exactly. The delay "E" as computed by this formula is in addition to that for the Ground Station (0.180 statute miles), so that the sum of these two 'errors' gives the 'off scale' setting to the verniers.

THE RECEIVER.

The Receiver (R-15/APN-3) used in SHORAN equipment is an ultra-high frequency superheterodyne receiver. The same receiver is used in the Ground Station equipment. It is built as a separate component for ease of servicing, and replacement if necessary. The Receiver mounts in a space provided for it in either the Ship INDICATOR or the Ground Station MONITOR.

The general characteristics of the Receiver are:

Frequency tuning range	210 to 320 megacycles;
Band width	4 megacycles between half-power points;
Sensitivity	2.5 microvolts (9 db.)above thermal noise;
Input Impedance	50 Ohms
Output Impedance	500 Ohms


AVERAGE CALIBRATION OF TUNING DIAL
RECEIVER AN/APN-3
DIAL SETTING
FREQUENCY IN MCPS
0210 210
1445 220
0615 230
0765 240
0900 250
1020 260
1125 270
1225 280
1320 290
1405 300
1480 310
1545 320
FREQUENCY IN MCPS.
320
310
300
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280
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220
210
DIAL SETTING
200
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EUGENE DIETZGEN CO. NO. 346 A

FIGURE 7.

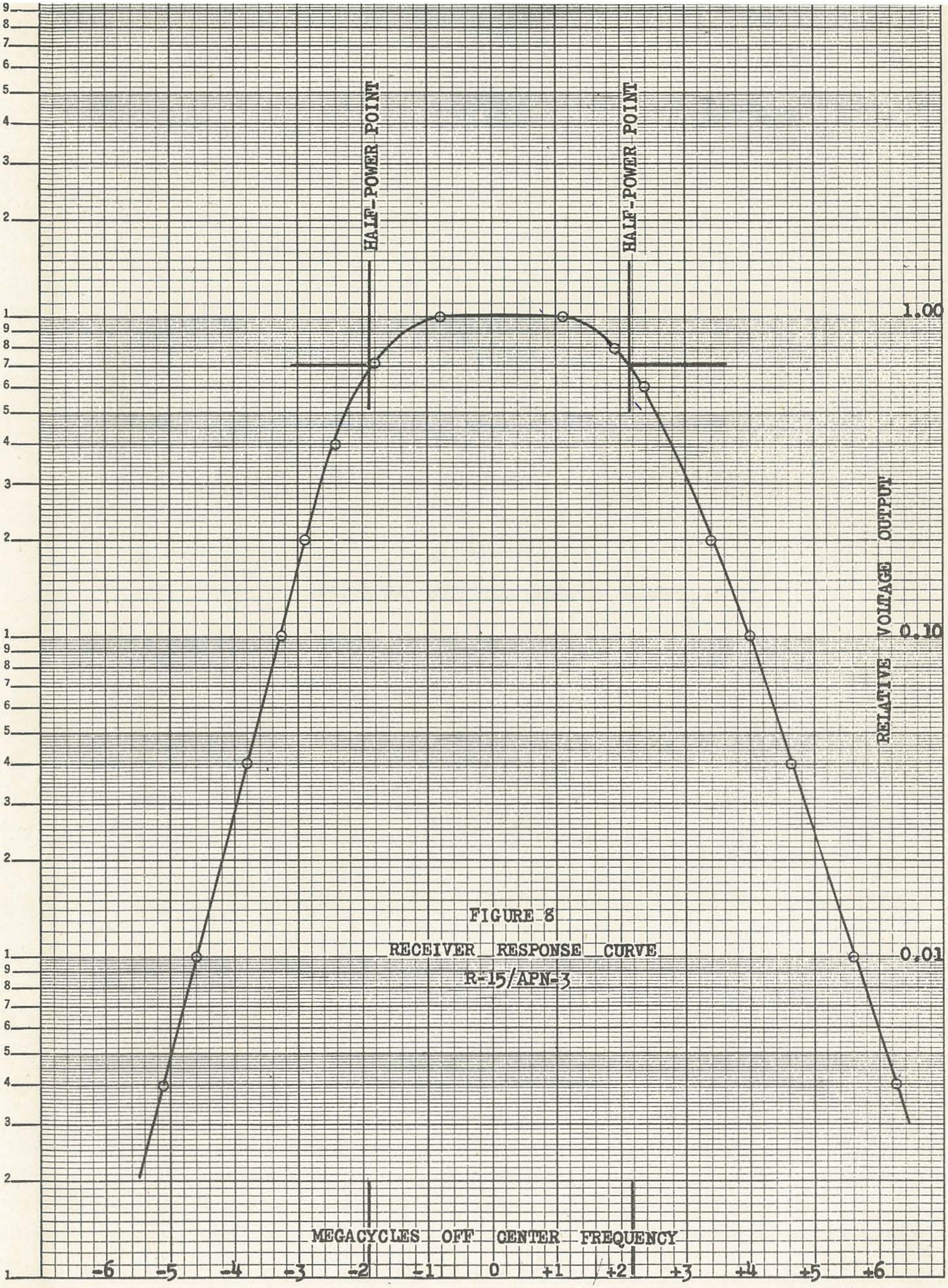


FIGURE 8

RECEIVER RESPONSE CURVE

R-15/APN-3

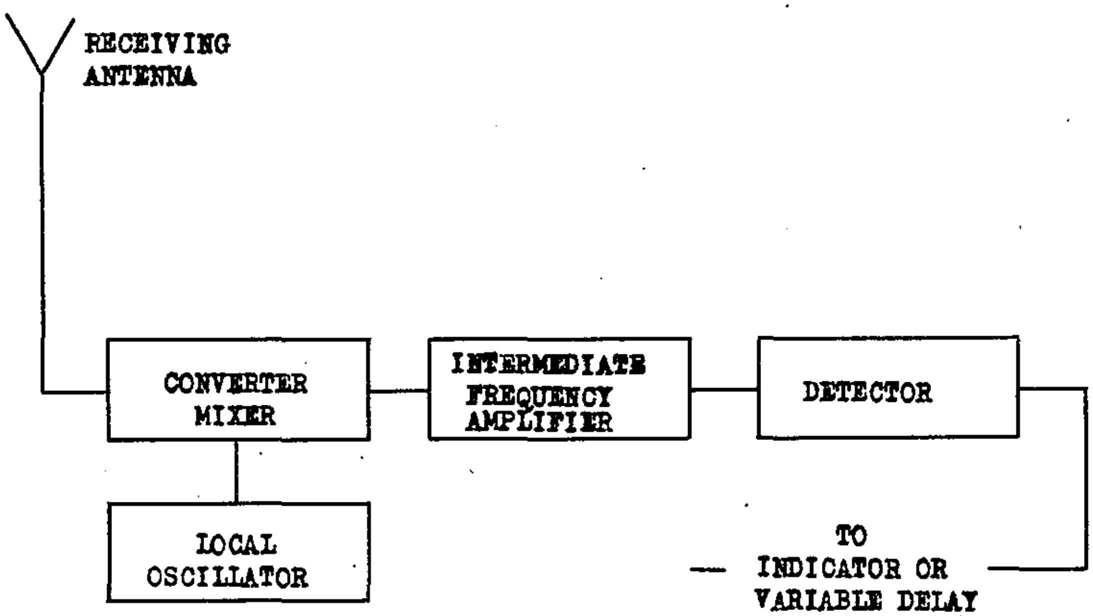


FIGURE 9.

BLOCK DIAGRAM OF THE RECEIVER.

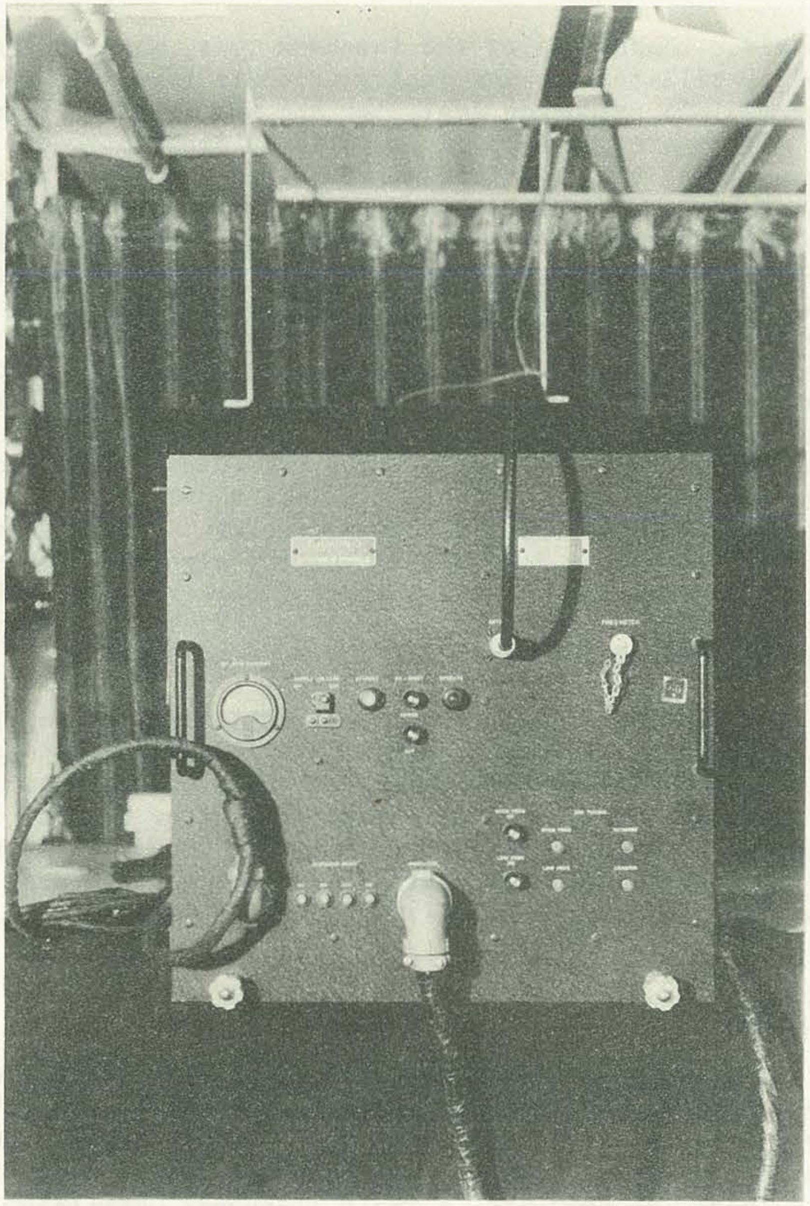


FIGURE 10.

THE TRANSMITTER - SHIP EQUIPMENT

An average tuning curve for the Receiver is given in Fig. 7, and the Receiver Response Curve in Figure 8. The Block Diagram of the Receiver is shown in Fig. 9. As indicated, the incoming signal enters through a Converter where it is mixed with the Local Oscillator (LO) frequency, then passes through six stages of Intermediate Frequency (IF) amplifiers, and finally through a detector to the proper terminal in the Indicator (or Monitor) chassis.

The Receiver chassis is of the two-deck type, wherein the Converter, Local Oscillator and the Tuning Circuits form the Upper Deck; and the Intermediate Frequency Amplifier and the Detector form the Lower Deck. The Converter tube is inductively coupled to the Antenna, and its tuning line, the Grid Transmission Line, is tuned by a shorting bar controlled by a hand-wheel with a counter system attached to indicate the relative position of this Shorting Bar. This hand wheel also tunes the Local Oscillater which has a similar transmission line and shorting bar, and keeps it tuned to the desired 30 megacycles above the incoming received signal. The inductance between these two transmission lines mixes the two signals - the incoming with the Local Oscillator, with the result that a frequency of 30 megacycles is passed on to the Intermediate Frequency Amplifiers. This I.F. amplifier is of the "staggered-tuned" type, where the input, 2nd., and output transformers are tuned to 30 megacycles; the 3rd. and 4th. are tuned to 27.8 megacycles; and the 5th. and 6th. are tuned to 32 megacycles. This system of "stagger-tuning" enables a Receiver to amplify signals which might be considerably off frequency - by as much as 2 megacycles - without great change in output value. This can be readily seen by an examination of the Receiver Response Curve mentioned above (Fig. 8).

Since this Receiver has to receive signals from two separate sources which might have a very considerable difference in signal strength, it is provided with two gain controls, one for each of the two Ground Stations. These two gain controls, being brought through to the Indicator, are further controlled by the COMUTATOR in the Transmitter, so that the particular control is effective only when signals are being transmitted (and received) from a particular Ground Station.

THE TRANSMITTER.

The Block Diagram of the Transmitter (code name T-11/APN-3) and a photograph of this unit are shown in Figs. 10 and 11 respectively. In this block diagram, it is seen that the 'keying' pulses are received from the Indicator Unit. They are corrected in shape, amplified, and then used to 'key', or modulate, a radio frequency Oscillator, which sends corresponding pulses of radio-frequency energy to the transmitting antenna (dipole). The Transmitter also acts as a distribution center for power to the Indicator. The general functioning of the circuits in the Transmitter are briefly described as follows:

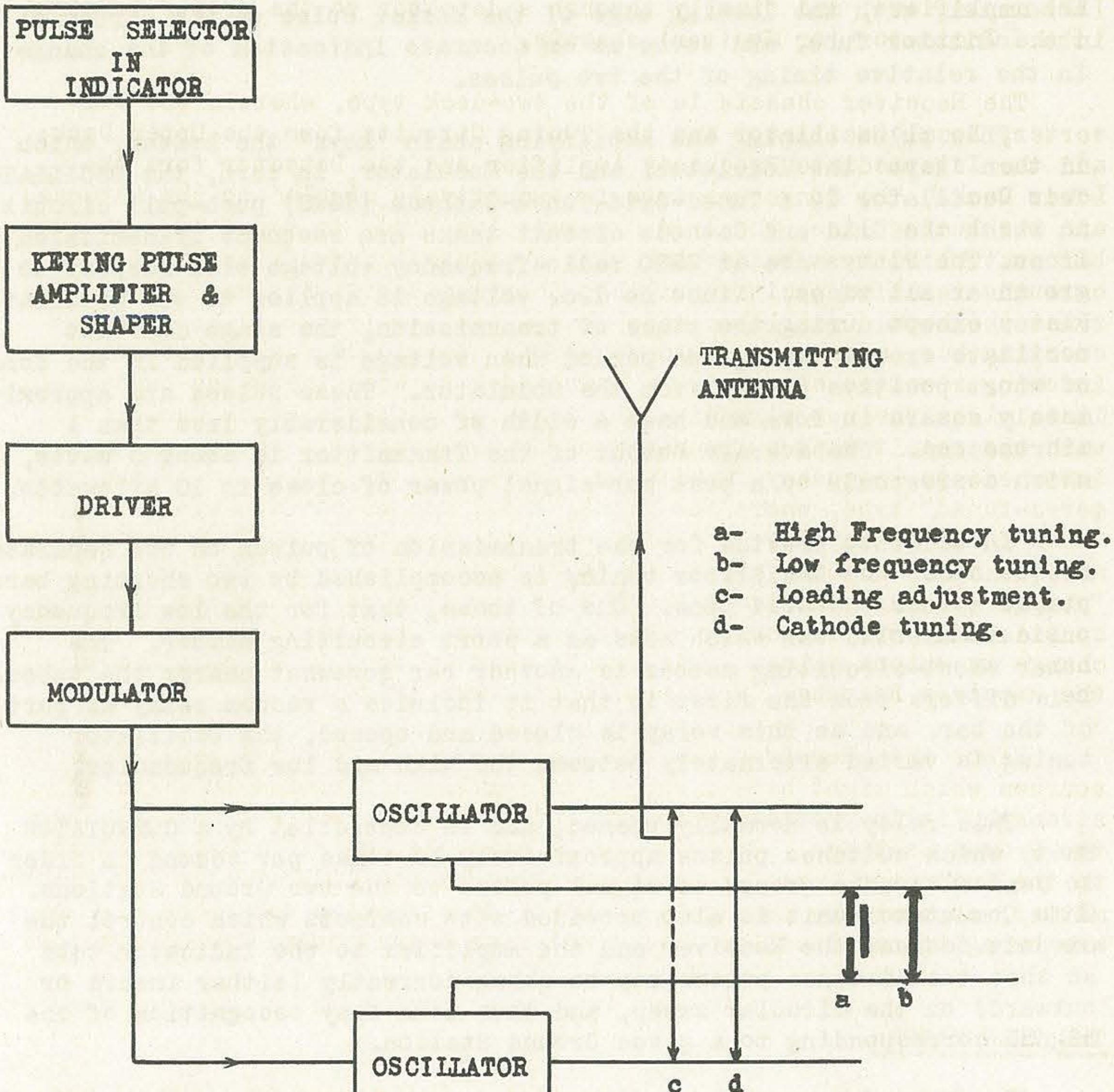


FIGURE 11.

SIMPLIFIED BLOCK DIAGRAM OF THE RECEIVER.

Pulses generated in the Indicator Unit and supplied to the Transmitter are timed and shaped in such a way that timing of their leading edges is relatively free from variation due to changeable tube or circuit conditions. The leading edges of the pulses returning to the Ship after the round-trip to the Ground Station can therefore be aligned accurately with the leading edge of the Marker Pulse on the screen of the Indicator Tube, and serve as an accurate indication of the change in the relative timing of the two pulses.

This pulse shaping and amplifying chain 'keys' the Driver, which in turn 'keys' the Modulator; and the Modulator, in turn, the OSCILLATOR. This Oscillator is a Tuned-Grid-Tuned-Cathode (TGTC) push-pull circuit in which the Grid and Cathode circuit tanks are resonant Transmission Lines. The Plates are at ZERO radio-frequency voltage with respect to ground at all times. Since no d.c. voltage is applied to the Oscillator Plates except during the times of transmission, the stage does not oscillate except during the period when voltage is supplied in the form of short positive pulses from the modulator. These pulses are approximately square in form and have a width of considerably less than 1 microsecond. The average output of the Transmitter is about 3 watts, which corresponds to a peak per-signal power of close to 10 kilowatts.

In order to provide for the transmission of pulses on two separate frequencies, the Oscillator tuning is accomplished by two shorting bars placed across the Grid Line. One of these, that for the low frequency pulse is a solid bar which acts as a short circuiting member. The other short-circuiting member is another bar somewhat nearer the tubes. This differs from the first in that it includes a vacuum relay as part of the bar, and as this relay is closed and opened, the Oscillator tuning is varied alternately between the high and low frequencies.

This relay is normally opened, and is controlled by a COMMUTATOR Unit, which switches pulses approximately 10 times per second in order to send alternate groups of signal pulses to the two Ground Stations. This Commutator unit is also provided with contacts which control the circuit between the Receiver and the Amplifier to the Indicator tube so that the distance pulses may be shown correctly (either inward or outward) on the circular sweep, and thus make easy recognition of the signal corresponding to a given Ground Station.

The Transmitter can be tuned over a frequency band of about 50 megacycles, from 210 at the lower end to about 260 mcps. at the higher end. Since the Receiver is quite broad-banded, it will receive signals about 2 megacycles either side of the mid-frequency to which it is tuned. Therefore, the exact tuning of the Transmitter is not so vital, although this can be accomplished within very narrow limits - about 0.10 megacycle. There is some variation of transmitted frequency with time and age of tubes: it is necessary to make occasional checks of the adjustments. (The Oscillator is provided with a Cathode Tune and a Load

Adjustment. Neither of these adjustments effect the Oscillator frequency greatly if the settings are only approximately correct.)

THE ANTENNAS AND TRANSMISSION LINES.

The Antenna system of the SHORAN Ship Station consists of two special vertical antennas which are connected to the Transmitter and to the Receiver by high-frequency Transmission Lines.

The Receiving and Transmitting Antennas follow the same design principles, but their dimensional differences are due to the difference in the frequencies under which they operate. Essentially, the antenna is a quarter-wave dipole working against the ground plane on which it is mounted. The antenna is fed, not at the base as is commonly done, but at a point at some distance above it to provide greater stability of impedance with frequency. This feature is necessary because each dipole must present reasonably constant impedance over the entire frequency range of the associated Receiver or Transmitter.

The antenna proper consists of two metallic parts. The outer, a short tube is electrically connected to the ground plane through a mounting flange; the inner, a short length of rod, about twice as long as the tube, extends through the tube and is insulated from it by a low-loss bushing. This forms a short section of Co-axial line where the rod is inside the tube. The Co-axial section acts as a coupling and impedance matching device to connect the antenna which has an impedance of about 100 ohms to the Transmission line with an impedance of 52 ohms.

The length of the antenna determines the operational frequency. Therefore, in the ship equipment, the Receiving Antenna is shorter than the Transmitting Antenna, for the respective frequency ranges are 290-320 mcps, and 210-260 mcps. The diameter of the rod has the effect of broad-banding the antenna, which is very desirable in this equipment.

The transmission lines are of special high-frequency solid-dielectric Co-axial cable, with an impedance of about 52 ohms, and a propagation constant of about 0.65 (i.e. the velocity of the electromagnetic wave in the cable is 65% of that in free space, which is the value used in the formula given in an earlier section.)

THE GROUND STATION.

Radio Set AN/CPN-2 (Army Navy Ground Radar Navigation Equipment Type 2) is the code designation of the Ground Station equipment. Since no separate frequency channels are required for Ships operating on SHORAN equipment, one pair of Ground Stations will accomodate a relatively large number of Ships. Of course, Ground Station power considerations limit the number of ships operating simultaneously from a pair of these stations to about 20 as a maximum. For power economy,

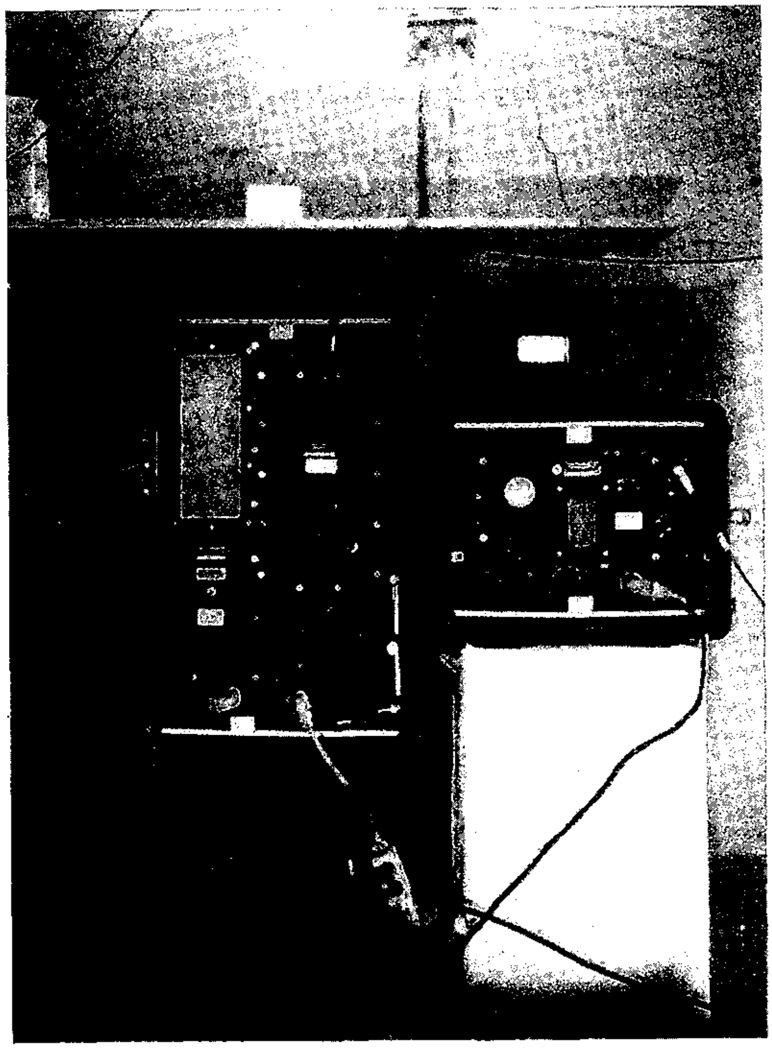


FIGURE 12.

GROUND STATION EQUIPMENT

TRANSMITTER - LEFT
MONITOR - RIGHT.

the Ground Stations use a directional Antenna System; therefore, ships using the same pair of Stations must be somewhere in the same general direction or area. However, where the distance to the Ground Stations is not large, the directional reflectors may be dispensed with, with the result that there is a 360° radiation of the electromagnetic energy, but with a reduction in power over a given direction.

The Ground Station equipment consists of a MONITOR and its RECEIVER, a TRANSMITTER, an ANTENNA SYSTEM on an elevated MAST, and two gasoline-driven POWER UNITS. These are described in the following paragraphs.

THE MONITOR.

The Monitor (ID-12/CPN-2) is the central control unit of the Ground Station. In operating service, most routine checks can be performed by the operator at the Monitor panel, excepting, of course, starting and stopping the Power Units. A photograph showing an installation of the Ground Station equipment is shown in Fig. 12. Earlier in this discussion, it was pointed out that the Ground Station consisted essentially of a Receiver and a Transmitter interconnected so that signal pulses received could be amplified and used to key a Transmitter to return them to the Ship Station. This Receiver, which is identical with that in the Ship equipment, is housed in the Monitor and together form the Monitor Unit. The Transmitter is separate, as shown in the photograph: the Transmitter is on the left, and the Monitor on the right.

The Monitor contains a large number of circuits necessary for the correct functioning of the Ground Station. An over-all picture of these circuits may be gotten by a study of the Block Diagram in Figure 13. This block diagram shows the general way in which each circuit serves its purpose in the equipment. As with other diagrams, this shows only the features which are described below, and does not necessarily show all the functional features as some are purposely omitted for clarity.

The OSCILLATOR is a crystal controlled oscillator and is the Master Timing frequency of the entire system - both Ground and Ship equipments. This frequency is 93109 cycles per second. Frequencies derived from this oscillator are 93109 cycles, 9310.9 cycles, and 931.09 cycles. The crystal is of great precision, and is housed in a temperature controlled oven, where at a temperature of 70° Centigrade, it will maintain this frequency with a minimum drift. The two partial harmonics of the master crystal are required for tests and in checking the functioning of the equipment. They are referred to as the 93 kc., the 9.3 kc., and the 0.93 kc. frequencies for brevity.

The Monitor serves the purpose of determining the correct functioning of the Ground Station equipment at all times. There is a Function Switch which connects various circuits to the Indicator Tube, and

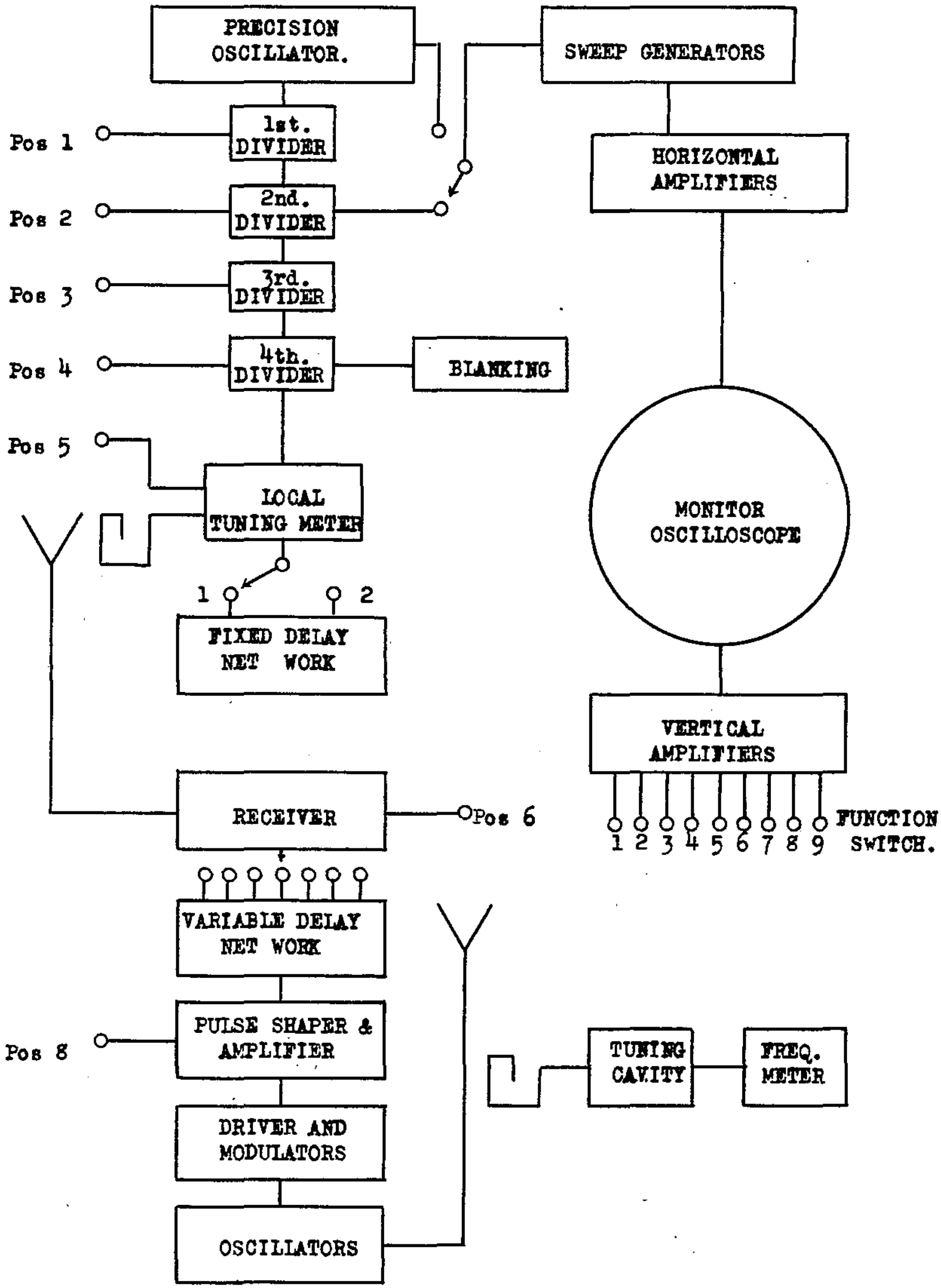


FIGURE 13.

SIMPLIFIED BLOCK DIAGRAM OF THE GROUND STATION EQUIPMENT.

therefore the operator can tell at a glance whether the equipment is functioning correctly or not. The various operating functions are checked on the first seven (7) positions of this switch. Direct re-transmission of pulses received from the Ship is effected only in positions (8) and (9) which are marked 'OPERATE-MONITOR' and 'OPERATE'.

In either of these two latter positions of the Function Switch, the following signal path is set up. Pulses originating at the Ship Station are received on the Antenna, amplified and detected in the Receiver. The selectivity of this Receiver is such that it will not accept signals which are intended for another Ground Station. The Output pulses of the Receiver go to a Variable Delay Network which is an artificial Transmission Line consisting of many sections made up of capacitors and inductances. These pulse signals, in passing down this chain of circuit sections, are delayed a fixed amount in each section, and pulses delayed by the accumulated amount due to any number of sections can be picked off at will by connecting the output terminal to the desired section. This delay per section is approximately 0.05 microsecond, or in this case where the delay line consists of 20 sections, the total delay is a maximum of 1 microsecond. The purpose of this delay network is to enable the operator to standardize to a predetermined value the over-all delay in the Ground Station equipment. This delay must be standardized, for any uncontrolled variation from a fixed known value will cause a variation in the total round-trip time which the signal pulse is supposed to measure.

While the Ship Station equipment depends upon an Oscillator of great stability and accuracy for correct distance measurements, the crystal is subject to a small frequency drift due to temperature changes during the operating period, against which there have been no provisions made to guard it due to the necessity of saving in weight and space of the air-borne equipment. Therefore, provision has been made at the Ground Station to generate and transmit trains of pulses with an accurately fixed repetition rate, which the Ship operator may receive and use as a standard frequency in adjusting the Ship Station Oscillator. As the nominal repetition rate of these pulses is 9.3109 kcs., they will appear as stationary on the Ship Indicator if that frequency is 9.3109 kcs. However, if they move around the sweep, it will indicate that the Ship Oscillator is too fast or too slow depending upon whether they move clockwise, or counterclockwise. This is corrected, in the Ship, by adjusting a small variable condenser (CAL ADJ) on the Indicator panel until the pulses are stationary. This adjustment will take care of a drift of from -5 to +10 cycles per second.

For this type of service, the Function Switch is set on 'Monitor-Operate' or position (8). The pulses transmitted by the Ground Station Transmitter are picked up by the Receiver in the Monitor and routed in the same path as a signal from the Ship Station. On this position of the Function Switch, both the received pulses from the Ship and the Calibrating pulses are transmitted to the Ship. In position 'Operate' (9), only the received signal pulses are re-transmitted.

Station-Delay Checking is performed with the Function Switch in 'Monitor-Operate', the same as used for transmitting standard timing pulses for Ship Station CAL ADJ. At any time that the Ground Station operator is checking his Station Delay, the equipment is also sending out timing pulses. This is necessary, because, in order to check the Station Delay, it is necessary to send a signal around the entire path, within the equipment, of the signal to be re-transmitted in the Ground Station.

This is accomplished by generating two pulses in the r.f. generator. One r.f. pulse is picked up by the receiver and passes through the same path that the re-transmitted signal follows: the Receiver, the Variable Delay Network, and leaving the Station from the Transmitter Antenna. The other is a demodulated Oscillator Grid pulse envelop, which passes through a FIXED DELAY NETWORK.

This Fixed Delay Network is the standard of time used in the Station Delay measurement, and when the transmission time through the re-transmission circuit consisting of the Receiver, the Variable Delay Network, the Transmitter and all the associated components is made equal to the re-transmission time through the Fixed Delay Network, the Station Delay has been standardized at 0.180 statute miles. This delay takes into account the length of the transmission lines between the antenna array and the Monitor-Receiver and the Transmitter as well as all other circuit delays. The pulse, after passing through this Fixed Delay Network, passes to the input of the Transmitter, where it is reshaped and amplified, and finally 'keys' the Transmitter Oscillator in a manner similar to that in the Ship Station equipment.

With the Function Switch set at Pos. 8 ('Monitor-Operate'), these two pulses appear on the screen of the Indicator Tube in the Monitor. It is then only necessary to adjust the Variable Delay Network (ZERO ADJ) until the leading edges of the two pulses are in coincidence. Thus, we have two pulses starting out at the same time. One travels through the Ground Station Receiver and Transmitter and all intervening circuits experiencing a time delay which is called the CIRCUIT DELAY. The other travels through a network which introduces a fixed delay in its transmission. Both finally end up at the Oscilloscope where the traces on the cathode ray tube screen will coincide if they have experienced the same time delay. By introducing into the Receiver-Transmitter (or, re-transmission) circuit a variable time delay, it is possibleto adjust this delay so as to cause the desired coincidence. This measures only the delay experienced within the equipment, and does not consider the delay due to the transmission lines between the antenna system and the Ground Station equipment. However, for a fixed length of transmission line, this delay will be constant, and can be computed with the required accuracy. If this delay is added to the circuit delay, the over-all delay is known. If it is desired to keep the over-all delay at 2 microseconds, the station delay can be standardized at a value somewhat less than the 2 microseconds by subtracting the delay time caused by the transmission lines to the two antennas.

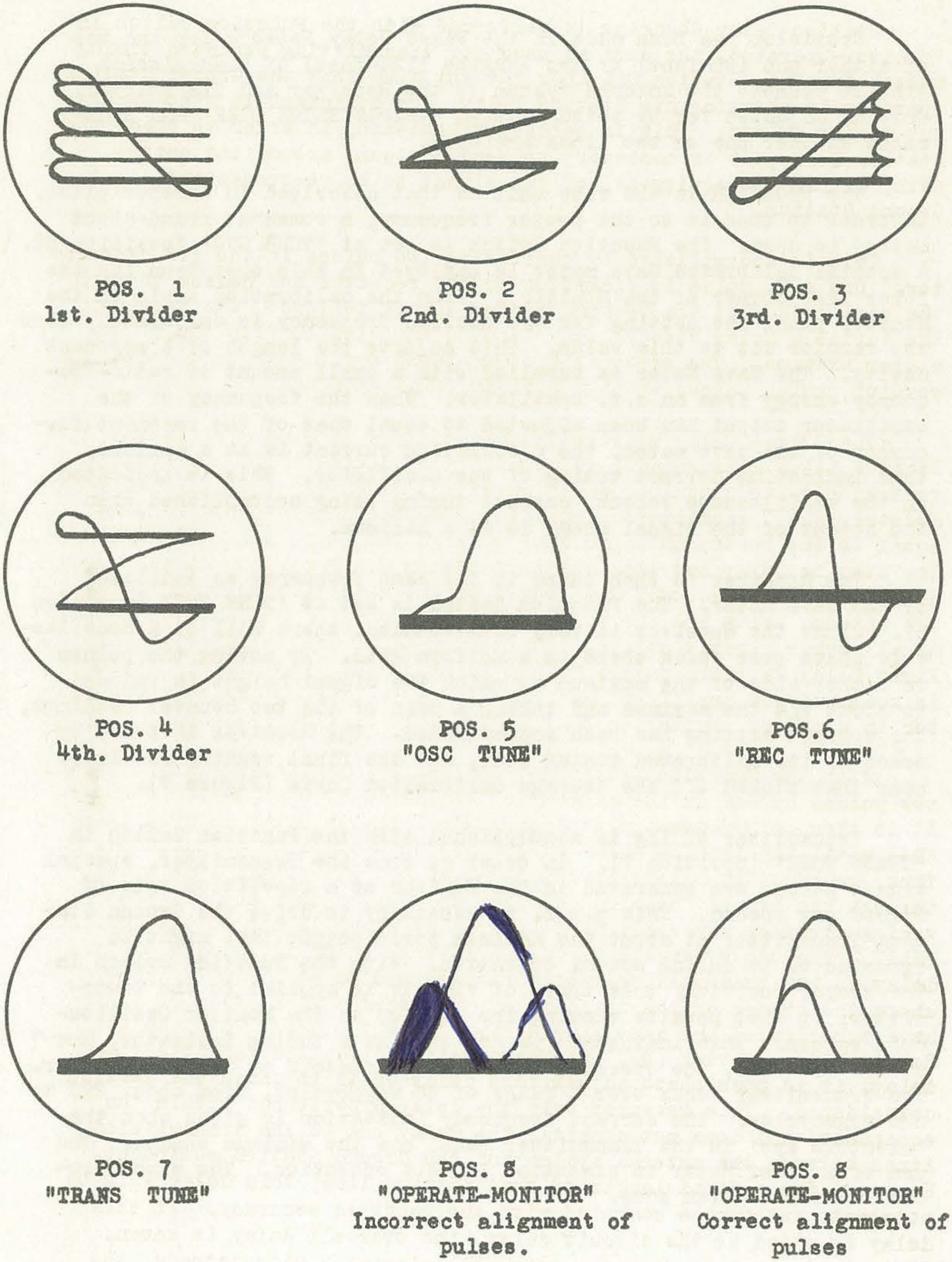


FIGURE 14.

OCSILLOSCOPE PATTERNS - FUNCTION SWITCH.

Provision has been made in the Fixed Delay Network for the use of either one (82-feet) or two lengths (124-feet) of transmission line to connect the Antenna system to the Receiver and Transmitter. This is adjusted for by switch marked 'TRANSMISSION LINE' and indicates whether one or two lines are used.

The RECEIVER is the same unit as that described in another place. In order to tune it to the proper frequency, a somewhat round-about method is used. The Function Switch is set at 'TUNE OSC' (position 5). A special calibrated wave meter is employed in this operation (in the lower left corner of the Monitor). From the calibration table on the Monitor panel the setting for the desired frequency is calculated, then the vernier set to this value. This adjusts the length of a resonant cavity. The Wave Meter is supplied with a small amount of radio-frequency energy from an r.f. oscillator. When the frequency of the oscillator output has been adjusted to equal that of the resonant frequency of the wave meter, the circulating current is at a maximum, thus indicating correct tuning of the Oscillator. This is indicated on the oscilloscope screen, correct tuning being accomplished when the height of the signal shown is at a maximum.

The Receiver is then tuned to the same frequency as indicated by the wave meter. The Function Switch is set at 'TUNE REC' (position 6). Since the Receiver is very broad-banded, there will be a considerable space over which there is a uniform gain. By noting the points on either side of the maximum at which the signal height is reduced to about 1/4 the maximum and taking a mean of the two counter readings, the correct setting has been accomplished. The Receiver is tuned by means of its calibrated tuning dial, and the final reading should be near that picked off the Average Calibration Curve (Figure 7).

Transmitter tuning is accomplished with the Function Switch in "TRANS TUNE' (position 7). In order to tune the Transmitter, special signal pulses are generated in the Monitor at a repetition rate of 9310.9 per second. This p.r.f. is necessary to drive the Ground Station Transmitter at about the maximum power output that might be expected of it during actual operation. With the Function Switch in the proper position, this train of signals is applied to the transmitter; it also permits viewing the envelop on the Monitor Oscilloscope screen. This indication is not used as a tuning indicator, however. For this, the operator must station himself at the Transmitter. The Transmitter tunes over a range of 40 megacycles, from about 290 to 330 megacycles. The correct frequency indication is given when the 'electric eye' in the Transmitter panel has the minimum shadow. The use of a Power Meter is essential in this operation. The exact procedure is not given here.

Other Functions of the Equipment are shown when the Switch is in one of the positions (1), (2), (3), or (4). These positions show the operation of the frequency dividers. Positions (1) and (3) show divisions by 5; and positions (2) and (4) show divisions by 2; or, in other words, these four positions will indicate whether there is actually a division of frequency that will give exactly the frequencies mentioned in other paragraphs: 9.3109 kcs and 0.93109 kcs. These frequencies are required in various parts of the equipment such as sweep generators for the oscilloscope, station checking, and particularly generating standard timing pulses.

Sketches of the various Oscilloscope patterns for the different Function switch settings are shown in Figure 12. By use of the various adjustments which affect the oscilloscope, the patterns can be made to resemble those in the sketch very closely.

THE TRANSMITTER.

The Transmitter (T-12/CPN-2) is much the same as the Ship Transmitter. The main differences are that it has been designed to operate at a much higher average power output so as to accommodate as many as 10 or 20 ships at a time using SHORAN equipment; and that it operates on one fixed frequency instead of two. This requires the use of a more powerful modulator stage, but at the same time does away with the second shorting bar and vacuum relay in the Grid Transmission line. The average power output of this Transmitter is about 60 watts, with a peak power per signal of about 15 kilowatts. As in the Ship equipment, the Transmitter is the distribution point for power supplied to the Monitor and Receiver.

The ANTENNA SYSTEM is supported by a MAST 50 feet in height. The Mast consists of six (6) sections of telescoping tubing made of plywood. The Mast assembly is in the form of a section of constant strength; that is, it tapers from the larger section in the middle to the smaller section at each end. The two center sections are about 8-inches in diameter, the upper and lower sections about 7-inches; and the top and bottom sections about 6-inches. The weight of the Mast alone is about 90 pounds. The Mast is supported in the vertical position by three sets of stainless steel guys placed at about 17, 34, and 50 feet from the ground; and the spread at the base is about 20 feet, one guy from each set being brought to a common anchor. A front and side view of the Mast and Antenna system are shown in Figures 14 and 15.

The ANTENNA BASE consists of a stainless steel tubing frame-work with a screen of wires forming a reflecting surface as well as a ground plane for the Antennas. The base is roughly trapezoidal in shape, being about 16" wide and 14 feet long. There are two sets of REFLECTORS which form a part of the Ground Station Antenna system. These are secured to the Antenna Base in the form of a horizontal 'W', with the Reflectors vertical. The Reflectors meet each other and

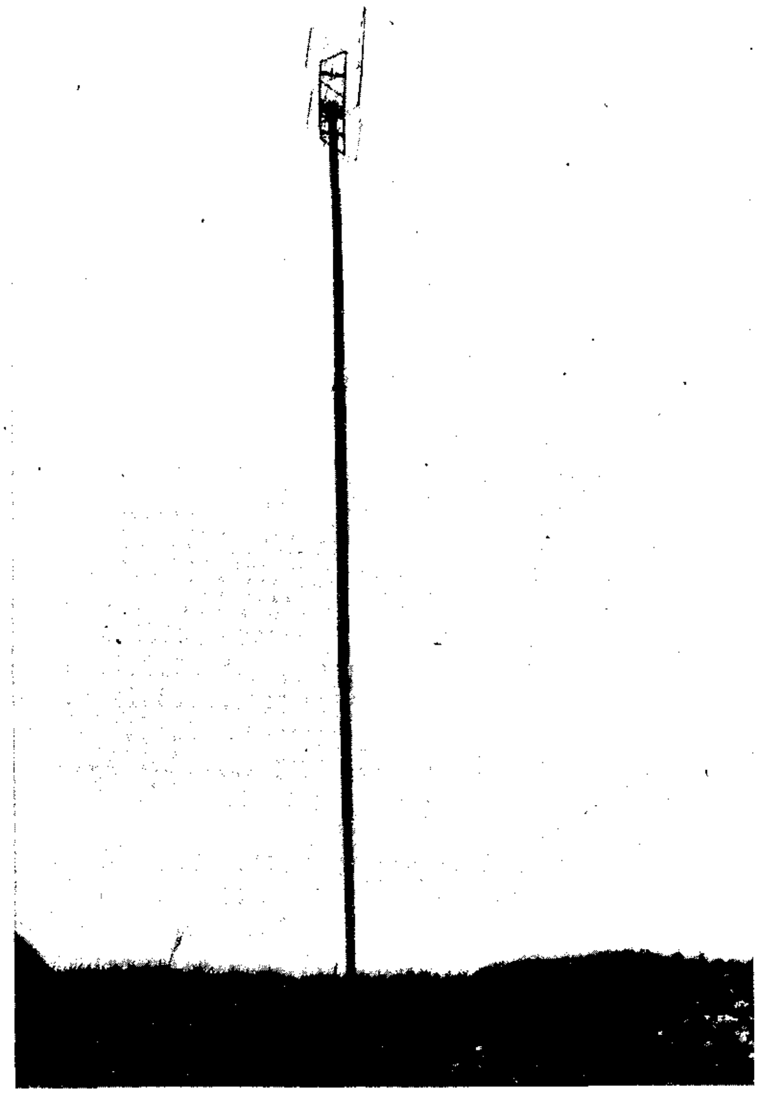


FIGURE 15.

MAST AND ANTENNA SYSTEM

GROUND STATION

SIDE VIEW

secure to the base at right angles (90°) and thus form a sort of "corner reflector" which gives a directional antenna pattern with a BEAM WIDTH of about 80°. This width of the field pattern is indicated by the points at the side of the polar diagram lobe where the field strength, the effective power gain is somewhat more than 5 as compared to 360° radiation without reflectors.

The Antenna Mast together with its guys and fastenings is first assembled on the ground with the base set in its final position. Suitable anchors, or deadmen are set at four points about 20-feet from the base, and so as to form a square, with one almost under the Mast, one on line with the center of the Mast (prolonged), and the other two at right angles to the Mast. The guy wires are laid out and those running to the anchors at right angles to the Mast are secured to them by means of the turnbuckles and short length of chain provided. Those guys which go to the anchor furthest along the line of the mast are secured to the end of an erecting boom; the boom is held in a vertical position by two rope guys going to the anchors at right angles to the Mast. There is secured to the upper end of the boom a block-and-tackle long enough to reach from the boom to the furthest anchor. When tension is applied to the block-and-tackle, the guys attached to the upper end of the boom are adjusted so that the mast assumes a perfectly straight line. The adjustments are made by means of turnbuckles. When the stays have been adjusted to make the mast straight, the masthead is elevated about three feet, and the Antenna Base and Reflectors attached to it. Finally, the two Antenna Dipoles are secured into position, the Transmission Lines connected to their respective Dipoles, run down the mast and secured to it, by means of the special fittings supplied. The erection of the Mast is then continued, making such adjustments as are required to keep the Mast straight, and go up as nearly vertical as possible without undue strain on the Mast or any of the stays. When in the vertical position, the boom end is secured to its anchor (or removed, and the stays secured to the anchor, as may be desired). Final adjustments are then made to all the stays to make the Mast straight and vertical. Figures 22 to 27 show the progress in the erection of the Mast and Antenna.

The Antennas are exactly similar to those used with the Ship equipment. However, they are reversed in their connections, for the Ground Station receives on the Low frequency, and transmits on the high frequency. Therefore, the longer dipole is connected to the Receiver; and the shorter one to the Transmitter, by transmission lines of the same characteristics as those described for the Ship Station.

THE POWER UNITS.

The Power Units are designated by the code PU-4/CPN-2. The motive power for this unit is a single cylinder gasoline, air cooled, two cycle engine. Its regulated speed is 4000 revolutions per minute. The

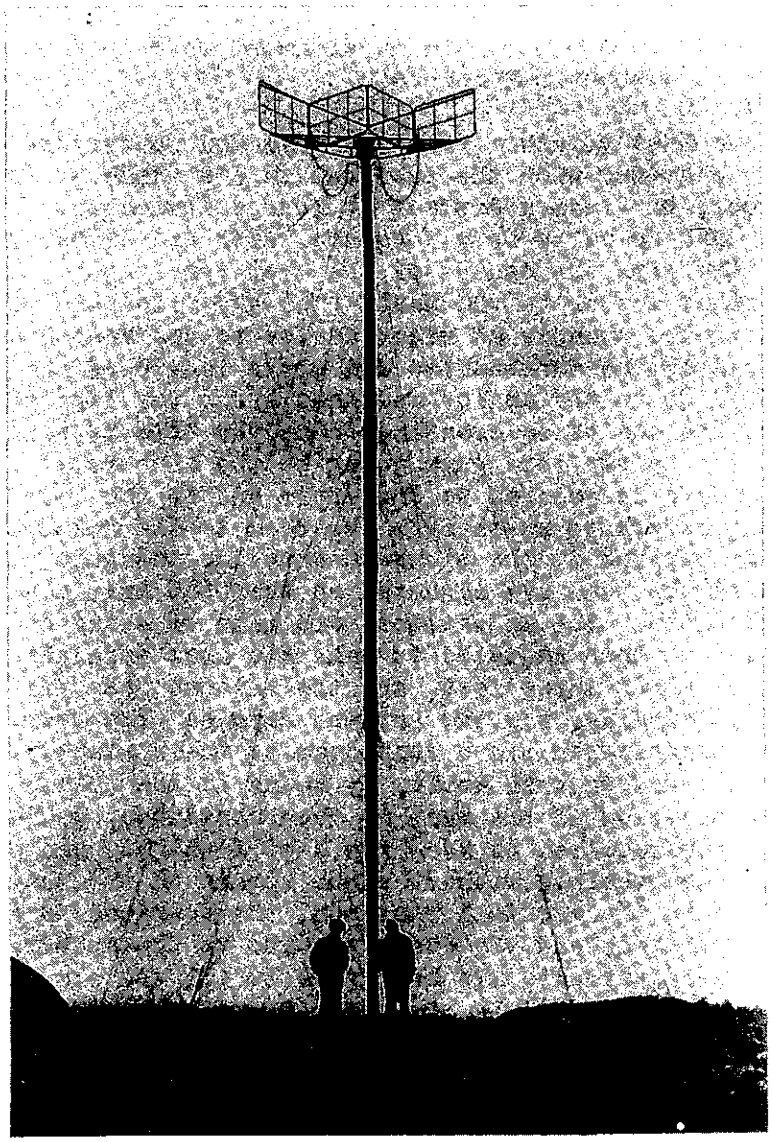


FIGURE 16.

MAST AND ANTENNA SYSTEM
GROUND STATION

FRONT VIEW

gasoline required is regular aviation 100-octane quality. The engine is provided with a one-gallon gas tank attached, and means of connecting an auxiliary five-gallon tank to it.

The generator assembly consists of a 1400-watt, 115-volt, 400-cycle inductor-alternator; and a 400-watt, 26-28-volt direct-current generator. The alternator rotor and the direct-current generator are mounted on a common shaft which is coupled directly to the engine crank-shaft. The alternator stator and the cirect-current yoke, brush assembly, and so on, are secured to the shell. A fan is provided which circulates great quantities of air around the engine.

The output a.c. voltage is regulated within narrow limits by means of a General Electric Voltage Regulator mounted on the generator end of the unit. There is provided means to make suitable connections to the Ground Station equipment by an outlet plug and cable, which carried both types of voltage to the Transmitter Unit.

Two Power Units are supplied with each Ground Station equipment in order that there may be as little delay as possible caused by power failures due to mechanical faults.

METHOD OF CALCULATING DISTANCES.

The distances between the Ship and the Ground Stations as indicated by the SHORAN equipment are not, in general, exactly equal to the great circle distances as they would be measured on the earth (or on the map or chart). This is illustrated in the Sketch of Figure 17a, where 'S' is the SHORAN distance, 'M' is the great circle (or map) distance, 'H' is the elevation (in feet of the Ground Station Antenna, and 'K' is the height (in feet) of the Ship Antenna. The indicated SHORAN Distance 'S' differs from the navigational distance 'M' for a number of reasons. These are classified as

1- Systematic errors
2- Random errors.

SYSTEMATIC ERRORS.

In the particular case in hand, it is desired to reduce the SHORAN distance 'S' to the correct MAP distance 'M'. The SHORAN distance is always greater than the Map distance, and therefore, if 'A' is this difference

$$M = S - A.$$

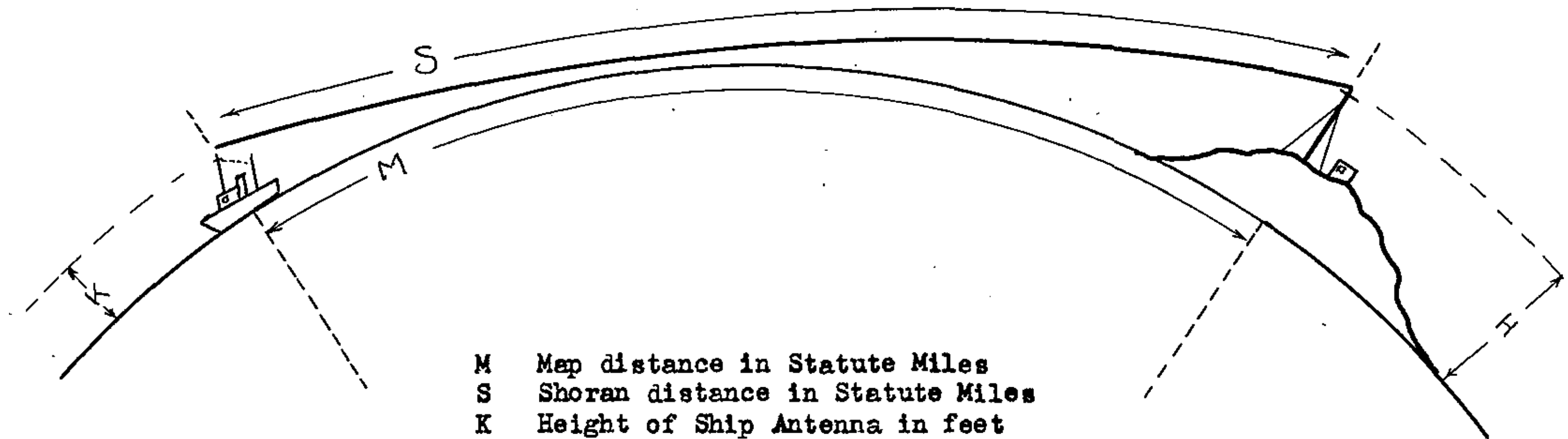
As will be shown later, the value 'A' is calculated from the SHORAN distance 'S', and that, since 'S' and 'M' are very nearly equal, the correction (or addition) to the Map Distance to read Shoran Distance may be computed from the same formula. Actually, however,

$$S = M + A^{o}$$

where 'A' and 'A^{o}' will differ by a very small amount on short lines. In this computation, some of the points to consider are:

1- The map distance 'M' is a great circle distance between the Ship and the Ground Station; that is, it is the shortest distance on the surface of the earth between the two points.

2- The SHORAN distance 'S' is the distance indicated by the equipment and will differ from the great circle for the following reasons: The end points of the SHORAN line are differend from the ground points, for the Ship Antenna is at a height 'K'-feet above the water, and the Ground Station is at a height 'H'-feet above the water. The SHORAN path is neither a straight line, nor a great circle line. Due to the varying amount of refraction due to the atmosphere, the SHORAN path can be very closely approximated by a circular arc with a radius of about 15,000 statute miles (or more closely as 3.91 timez the radius of the earth). Along the SHORAN path, the velocity of the radio waves cannot be everywhere equal to the velocity for which the equipment was designed to read correct mileages. The value chosen - 186,218 statute miles per second- is at standard sea-level barometric pressure of 29.92 inches of mercury, as explained elsewhere. Thus, the velocity varies along the path depanding upon the elevations of the particular points above the sea. Considered altogether, these corrections will make the error 'A' as great as 0.250 statute mile when the SHORAN distances and the elevations 'H' and 'G' are great (for example, 'S' = 200 miles, 'H' = 20,000 feet, and 'K' = 500 feet) as would be expected when the equipment was used in aerial navigation. The correction 'A' will therefore depend upon the elevations of the two pairs of antennas (Ship and Ground Station) as well as the measured SHORAN distance. This correction is given by the following formula:



M Map distance in Statute Miles
S Shoran distance in Statute Miles
K Height of Ship Antenna in feet
H Elevation of Ground Station Antenna in feet

FIGURE 17-A.

PATH OF THE ELECTROMAGNETIC WAVE.

$$M = \frac{2R}{2R + H + K}\left[S - \frac{(H-K)^2}{2S}\right] + \frac{S^3}{24}\left[\frac{1}{R^2} - \frac{1}{(3.91R)^2}\right] - \frac{(H-K)^4}{8S^3} \pm V.$$

If

$$A = \frac{2R}{2R + H + K} = 1 - \frac{H + K}{2R} + \frac{(H + K)^2}{2R} \quad ;$$

$$B = \frac{S^3}{24}\left[\frac{1}{R^2} - \frac{1}{(3.91R)^2}\right] = \frac{0.2483\ S^3}{10^8} \quad ;$$

$$C = \frac{(H - K)^4}{8\ S^3} \quad .$$

Then

$$M = A\left[S - \frac{(H-K)^2}{2S}\right] + B + C \pm V, \quad (V = \text{velocity correction})$$

and, if H and K are in feet, and M, S, and V are in Statute miles, this formula becomes:

$$M = S - \frac{2.3920\ S\ (H+K)}{10^8} - \frac{1.7935\ (H-K)^2}{10^8\ S} + \frac{0.2485\ S^3}{10^8} - \frac{1.6083\ (H-K)^4}{10^{16}\ S^3} \pm V.$$

and, it will lend itself to tabular computation of the various combinations of H and K. It will be seen from a casual inspection, that, where both H and K are small, that at least the fourth term will be negligible. If S is relatively small as well, (5-50 Mi.), then the correction 'A' will be practically ZERO, since all terms are divided by 10^8. In any case, except for very short lines where the actual slope distance correction will apply, this correction does not exceed 0.001 statute mile where S = 50 statute miles.

S in Miles	K in Feet	H in Feet	A in Miles
1	80	500	0.003
2	80	500	0.002
3	80	500	0.001
10	80	500	0.0004
25	80	500	0.0005
50	80	500	0.0007
3	80	1000	0.006
5	80	1000	0.003
10	80	1000	0.002
50	80	1000	0.002
100	80	1000	0.0005

S in Miles	K in Feet	H in Feet	A in Miles
3	80	1500	0.013
5	80	1500	0.007
10	80	1500	0.004
50	80	1500	0.003
100	80	1500	0.007.

As stated in a previous paragraph of this discussion, the velocity of a radio wave varies about 54 miles per second from the minimum of 186,218 miles at 29.92 inches mercury to 186,274 miles per second in vacuo. Assuming a straight line variation over this range (which is, of course, not exactly correct), a decrease in barometric pressure of 1-inch to 28.92 inches will make the velocity approximately 186,220 miles per second, or an increase of 1:93,000 (about). In a distance of 50 statute miles this correction is almost insignificant except where extreme accuracy is required.

RANDOM ERRORS.

The Random errors may be summarized as follows:

1- Setting and reading mileage verniers
Probable maximum . . . . ± 0.002 st.mi.

2- Non-linearity of timing phase shift circuits - the Goniometers
Probable maximum . . . . ± 0.010 st.mi.

3- Error of ZERO ADJUST in Ground Station
Probable maximum . . . . ± 0.005 st.mil

It is not probable that all errors will accumulate or occur at the same time. Laboratory tests seem to indicate that the maximum error in the ship equipment will not exceed 0.010 statute mile (+or -). It is possible that the Ground Station error due to the ZERO ADJ will not exceed 0.002 statute mile. This gives a maximum of about 0.012 mile or roughly, 50 feet.

The error in setting and reading the verniers is obviously a human error and varies with the individual. It cannot be actually measured.

The error in the phase shifting Circuits, or, properly, the GONIOMETERS, is due entirely to the manufacturing process which specifies certain tolerances as limits. An attempt has been made in the manufacture to design and place the inductances in such a way that there will not be a deviation from linearity of more than a few degrees at any point. A 4° deviation from linearity at any one point will correspond to about 0.010 mile. This error cannot be corrected for in the instrument as manufactured, but a calibration curve can be determined by laboratory methods which will give the deviation over the 360° of rotation of the Goniometers. This error then can be corrected according to the laboratory findings.

The error in the ZERO ADJ at the Ground Station is due to the characteristics of the Fixed and Variable Delay Lines in the Monitor. As was explained earlier, these lines are artificial transmission lines made up of sections composed of inductances and capacitors, the component values being selected so that each section delay time corresponds to about 0.005 statute mile, and that the ZERO ADJ Switch picks off the desired delay in steps of this magnitude. It will easily be understood that it is not probable that the ZERO ADJ will make proper coincidence of pulse pips in the 'scope at one particular section contact, that actual coincidence will be effected at some point between two sections. Since by the construction of the delay line, this is not possible, the error introduced here may be as large as 0.0025 statute mile. Further, the switch which selects the contact for one or two transmission lines operates over sections of the fixed delay line, and it is possible that the error in the selection may also be of the order of 0.0025 statute mile. If these are accumulative, this error can be 0.005 mile (+ or -). This error can be reduced only by greater horizontal amplification in the oscilloscope so that the deviation from exact coincidence can be seen; or by making one or two sections of each delay line variable over a small amount to equal this probable error. It is not practical to make these changes in the equipment in its present form.

THE UNCERTAINTY OF POSITION.

As stated above, the probable maximum error in any one reading is about 50 feet. As this error can be either plus or minus, and appears in any reading, there will be a certain amount of uncertainty in any one position. This is illustrated in the Sketch in Figure 17. The probable error in the distances measured will give a diamond-shaped area centered about the position as determined by SHORAN distances. It will be noted that the angle at which the two radio paths intersect at the position largely determines the size and shape of this figure of uncertainty. It will be seen that, at very small (30° or less) or very large (150° or greater) angles of intersection, the areas are the largest; and that at 90° the area is the smallest. Therefore, it would appear that the best determination of position will be when the angle of intersection of the radio paths is greater than 30° and less than 150°.

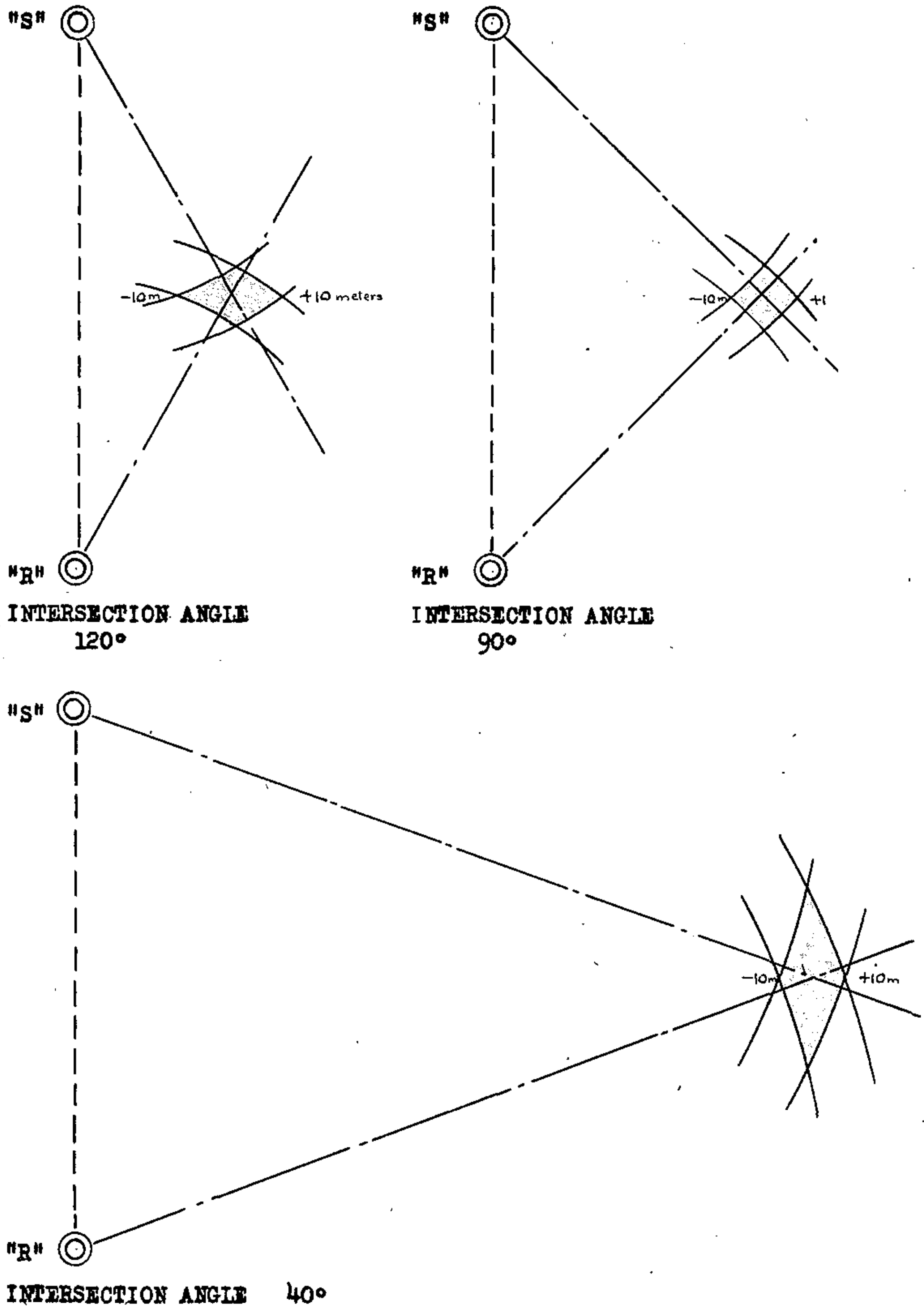


FIGURE 17.

POSITION UNCERTAINTY DUE TO RANDOM ERRORS.

On the reverse sides of Figures 28 and 29 are drawn arcs on which the intersection angles are 30°, 60°, 90°, 120°, and 150°. It will be observed that the area is almost entirely within the limiting curves of 60° and 120°, and that, only near the base line, does the angle become very large (180°) and the position indeterminate.

RANGE OF THE SHORAN SYSTEM.

As stated elsewhere, the radio path is neither a straight line nor a great circle line between the Ship and the Ground Station Antennas. The effect of refraction in the atmosphere on the radio path is to bend it downwards making the path roughly circular with a radius of about 15,000 miles (or more exactly 3.91 R of the earth). This makes the radio range about 16% greater than the optical range. The range can be approximated by the formula:

$$D = 1.42 \left(\sqrt{H} + \sqrt{K}\right)$$

It is probable, where both Ship and Ground Station Antenna are at low elevations, that the effects of refraction may be greater than indicated in the formula. The factor (1.42) is the value selected as most nearly giving correct ranges where elevations are fairly large as is the case when planes are used.

"SHORAN" FOR HYDROGRAPHIC SURVEY CONTROL

SHIP EXPLORER 1945

"SHORAN" is the name given to a precise SHORT RANGE NAVIGATION aid. It is a specialized adaptation of RADAR in which distances are measured with a very great degree of accuracy. The operation of SHORAN requires a Ship unit which is called the INDICATOR with its necessary auxiliary equipment (the whole unit being designated by the code AN/APN-3, which means: ARMY-NAVY AIR BORNE RADAR NAVIGATION EQUIPMENT Type 3); and two (at least) Ground Stations which are specialized repeaters (being designated by the code AN/CPN-2, meaning ARMY-NAVY GROUND RADAR NAVIGATION EQUIPMENT Type 2). There is a complete description of these equipments as part of this paper, in the section "HOW SHORAN WORKS."

In operation, the Ship equipment transmits short bursts of pulses to each of the two Ground Stations which receive and amplify them and return a similar pulse to the Ship equipment where it is amplified and shown on a cathode ray tube. If the time intervals between transmitted signals from the Ship and the Ground Stations can be measured, then the distances between the Ship and the respective Ground Station are also known since distance is equal to the product of time and velocity. Since the distances are radial distances from the Ground Stations, each can be represented by a circular arc, and the intersection of the two station arcs will be the required position. It will be assumed that the discussion on "HOW SHORAN WORKS" will have been read; therefore, this paper will be limited to the actual operation of the equipment in the field tests conducted by the Ship EXPLORER during the latter part of the 1945 field season in Alaskan waters.

EQUIPMENT RECEIVED.

The equipments received for these tests, which were to determine how well SHORAN would be adapted to Hydrographic Survey control, were:

On 6 August 1945, 4 Radio sets complete AN/APN-3;
24 August 1945, 2 Radio sets complete AN/CPN-2;
31 August 1945, 2 Sets test equipment.

The late arrival of these equipments precluded the operation of more than one ship on this work although there was equipment to operate two ships. Since the tests were to be conducted in areas remote from any repair or supply base, each ship was to be fitted with two equipments AN/APN-3 so that as little delay as possible would result from any break-down of equipment. There were four ground station equipments requisitioned, but only two arrived for the experimental work.

INSTALLATION OF THE SHIP EQUIPMENT.

Two Ship equipments were unpacked and inspected for completeness immediately after receipt on board. The balance of the equipment was placed in the Sound Locker for storage until needed.

The Bridge and the Radio Room of the ship had previously been surveyed for the best positions in which to install the two units of the equipment. These sites having been decided upon, suitable foundations were installed by the ship's forces and were ready for the placement of the equipment when it arrived. The INDICATOR was installed in the Bridge on the aft bulkhead just inboard from the "NMC" Echo Sounding Equipment. It was necessary to shift the "NMC" outboard about six inches to make sufficient room for the INDICATOR to clear the Chronometer case. This gave a very satisfactory arrangement of the equipment for use during the survey work conducted, as all personnel concerned were grouped in a small area near the plotting table.

The TRANSMITTER unit was installed in the Gyro-generator room on a foundation built just aft of the Power Stack of the DORSEY III Fathometer. This site provided plenty of space for air circulation, and, at the same time, allowed the necessary amount of accessibility to adjust the equipment. Further, since this part of the equipment makes considerable noise while running due to the blowers which circulate air around the transmitting tubes, this objectionable feature was reduced to a minimum.

This equipment requires the following power supplies:

600 watts	115 volt	400-2600 cycle alternating current;
150 watts	24-28 volt	direct current.

To furnish these two voltages in the required wattages, the 525-cycle motor-generator which is a component of the DORSEY III equipment, and the 24-28 volt genemotor which is the power supply for the ABK-4 equipment were used. A power cable was made up connecting these two power sources to the TRANSMITTER.

An interconnecting cable between the INDICATOR and the TRANSMITTER was made up, following very carefully the instructions in the Manual. This cable was 35-feet long, measured as about the shortest practicable

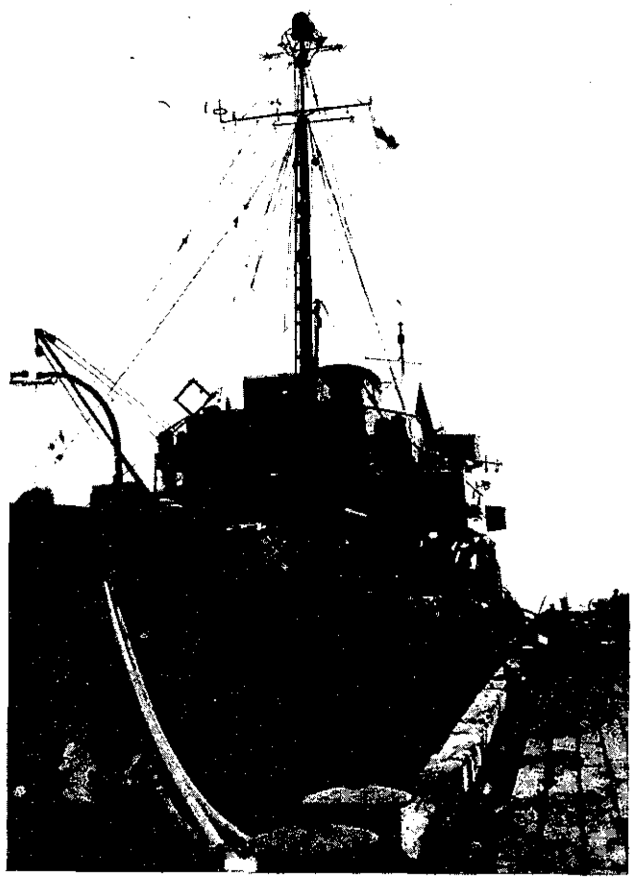


FIGURE 18. SHIP ANTENNA - FROM SHORE.

FIGURE 19.
SHIP ANTENNA - FROM BOW.

distance and in as direct a line as possible between the two units. The cable was laced and taped on completion. Holes were drilled through two bulkheads large enough to permit the connecting plugs to pass through. This was desirable for the reason that the cable could be made up more easily on the bench, and this arrangement permits the removal of the cable without unsoldering the connections.

Suitable cables of High Frequency Transmission Line were made up to connect the RECEIVER in the INDICATOR and the TRANSMITTER to their respective ANTENNAS. These cables were made up several feet longer than the installation required to allow for possible change in position of the equipment or the antenna base. These were both cut to a length of 75 feet. The Transmission Line to the TRANSMITTER was run up the star-board aft top stay of the mast; the line to the RECEIVER was run up the transmission line to the RADAR. Both were secured at intervals of about 18 inches by marlin.

The antenna BASES had been made up at an earlier date and were ready for installation. These consisted of two ground planes made up of aluminum angles with a suitable base for the antenna dipole. These bases were supported by an aluminum-angle frame-work secured to the protective cage at the base of the RADAR DOME at the truck of the fore-mast. The installation was secured by "U"-bolts to this frame. Several Photographs of the Antenna installation are shown in Figs.18-21.

The installation of the Ship equipment was completed on 20 August and the power was applied for a check on the equipment. (In the usual installation aboard a plane, the 24-volt DC power runs a 400 cycle AC inverter; if the DC power fails, no other power is applied to the equipment). The equipment is protected from damage by a DC relay which closes the AC line in this installation just in case there should be a failure of the protective device within the transmitter. This probably is just an extra precaution, and is not necessary. The DC power is necessary only to operate the blowers which circulate air around the transmitting tubes and in the Indicator and Transmitter spaces, but positively must always be on when the equipment is running.

This test run of the equipment was very satisfactory. Opportunity was taken to make preliminary settings for the receiver frequency of 310 MCPS and the Transmitter HIGH frequency at 250 MCPS, and the LOW at 230 MCPS. These latter frequencies were determined by means of a General Radio Wave Meter Type 758-A, which proved to be accurate within about 1 megacycle when later checks were made with a LaVoie Meter.

INSTALLATION OF GROUND STATIONS.

The late arrival of the Ground Station equipment determined more or less the area in which the experimental work was to be conducted.

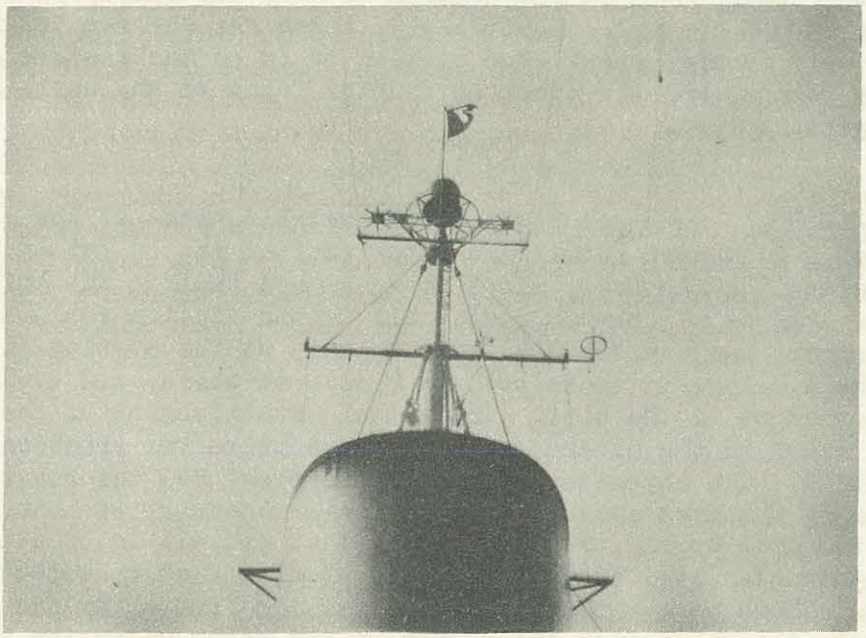


FIGURE 20. SHIP ANTENNA - FROM AFT.

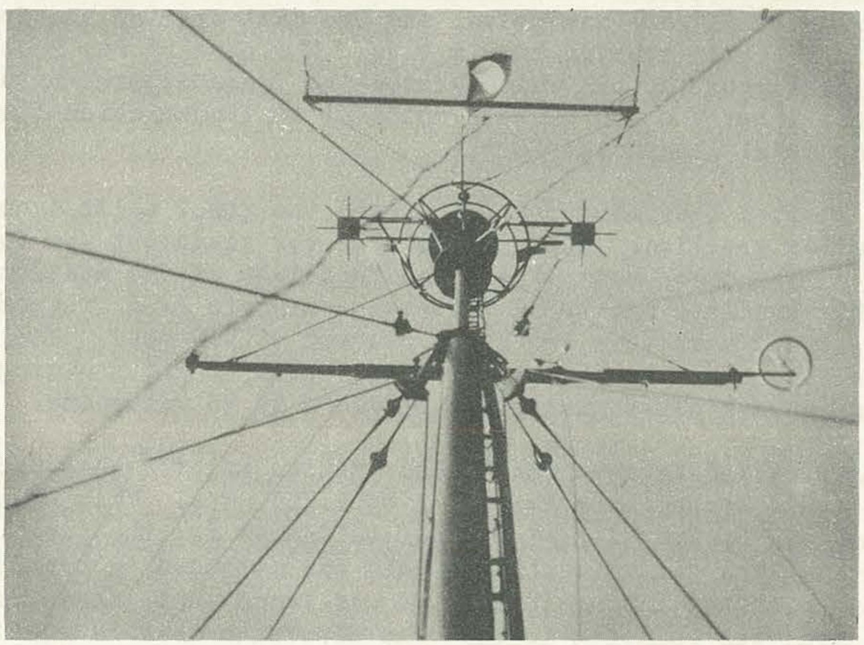


FIGURE 21. SHIP ANTENNA FROM BELOW.

A project for the survey of Ingenstrem Rock had been given the Ship late in the season, and it was decided to make the survey of this area with SHORAN control. Accordingly, sites for the two Ground Stations were decided upon: one station to be on the eastern end of Shemya Island, and the other on Kruglol Point on the north-eastern end of Agattu Island.

STATION "SHOR". Work was begun on the establishment of the Shemya Station on 5 September 1945. The site selected was on fairly high ground, elevation 22[illegible]-feet, close to an unused Pacific Hut built by the U. S. Army as a look-out post. All Ground Station equipment and camp equipment was transferred from the ship to the station site during the morning, by whale-boat from ship-to-shore, and by Navy truck from shore to the site. The actual establishment of the station was begun in the afternoon, with preparation for erection of the Antenna MAST. The character of the ground precluded the use of stakes for securing the mast stays: dead-men were necessary to insure support of the mast during the heavy winds that prevail in this area. The dead-men consisted of wooden frames about 2-feet by 4-feet made of 2x4's. These were buried at depths varying from a few inches to three feet, depending upon the nature of the earth under the tundra. The dead-men were weighted down with bags of sand available from the abandoned look-out post. This part of the work was the most difficult, and required about three hours to accomplish. The mast was assembled and the guy cables run out to their respective dead-men during the setting of the dead-men. The Antenna Base, antenna dipoles, and the transmission lines were assembled, and the mast erected the following morning in a little over an hour's time. The base of the mast was about 50 feet from the hut which housed the Transmitter-Monitor; this necessitated the use of both sections of transmission lines, making the total length 124 feet.

The station equipment was set up and the power units connected by the cables provided. The operation of the equipment was tested, and an over-all check made of all the functions of the station equipment. This Receiver was tuned to receive signals of a frequency of 230 mcps; the Transmitter frequency checked at 310 mcps. The power output as determined by a watt-meter was about 60 watts average, indicating a peak per-signal power of close to 15 kilowatts.

Communication between the Ground Station and the Ship was provided by radio 'phone on a frequency of 2.738 mcps. This equipment was loaned by the Army Signal Officer on Shemya for the duration of the project. The communication antenna was attached to the SHORAN mast just below the antenna base. It was found that, when the antenna array was pointing in the same direction as this communication antenna, there was enough pick-up, when using the phone, to cause the

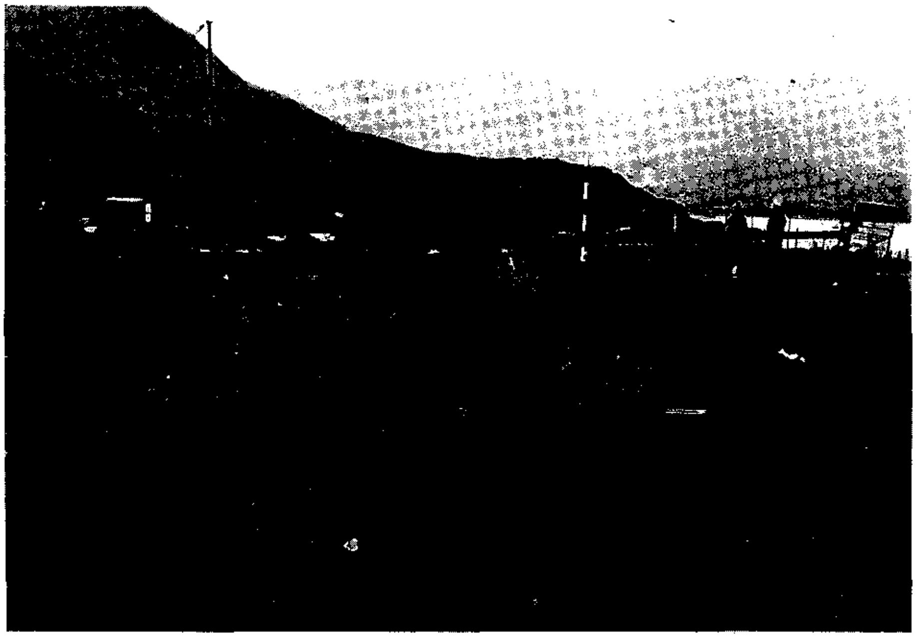


FIGURE 22.
MAST ASSEMBLED ON THE GROUND

FIGURE 23.
MAST BEING RAISED (1).

SHORAN Transmitter to over load and thus open the overload relay. This was not considered at all detrimental to the operation of the station since this particular pointing was little used. Receiver gain could be reduced to a minimum if necessary to use the 'phone.

The mast was located by usual triangulation methods from available stations near-by on the island. The elevation of the base was determined by dip-angles to the horizon. The elevation thus computed was 220 feet, which made the height of the dipoles 270 feet (the mast being 50 feet tall).

STATION "RAN". This station was to be established near triangulation station KRUG on the north-east point of Agattu Island. While this area was not in the practice-bombing area, the station which was marked by a large white-cloth-covered tripod seemed to be a particular favorite to the fliers. The area for several hundred yards about this point was well covered with bomb craters, and a particularly large number of unexploded parafrags lay near the station. There had been no explosion within ten yards of the station, although there were some 25 m "duds" within that radius of the station. A bomb disposal squad was brought from Attu to get rid of these bombs before the construction work could be started. It was also necessary to request that no further bombing in this area be done.

The 114th Construction Battalion (Navy) had been contacted previously with regards to the construction of a knocked-down hut to be used at this station. They not only were agreeable to the construction of the hut, but wanted to erect it as well. A weasel, material for the hut, and 6 barrels of gasoline were loaded on an LCT on the evening of 16 September, and taken to Agattu Island the following morning. A landing was attempted in the cove on the north side of the point near KRUG, but due to the low tide, the LCT could not get over the out-lying rocks, with safety. It was then decided to make the landing at MacDonald Cove (near the middle of the eastern side) where the material was landed. One load of equipment consisting of two halves of the floor and several small sections were taken to the site that evening. The following day two more loads of material were taken to the station and the hut partly erected. It was necessary to call off all operations due to a severe storm approaching, and the Ship ran to Attu. No further work was possible until 24 September, when the hut was completed. Due to the generally bad weather conditions which would prevail from this date on, it was decided to abandon, at least for the season, the plan of surveying Ingenstrem Rocks. Landings at the station would be difficult or require a long hike over the tundra from MacDonald Cove. Therefore, all the equipment which had been taken to the station was returned to the ship that evening. The hut, however, was secured for the winter and will be available for future operations.

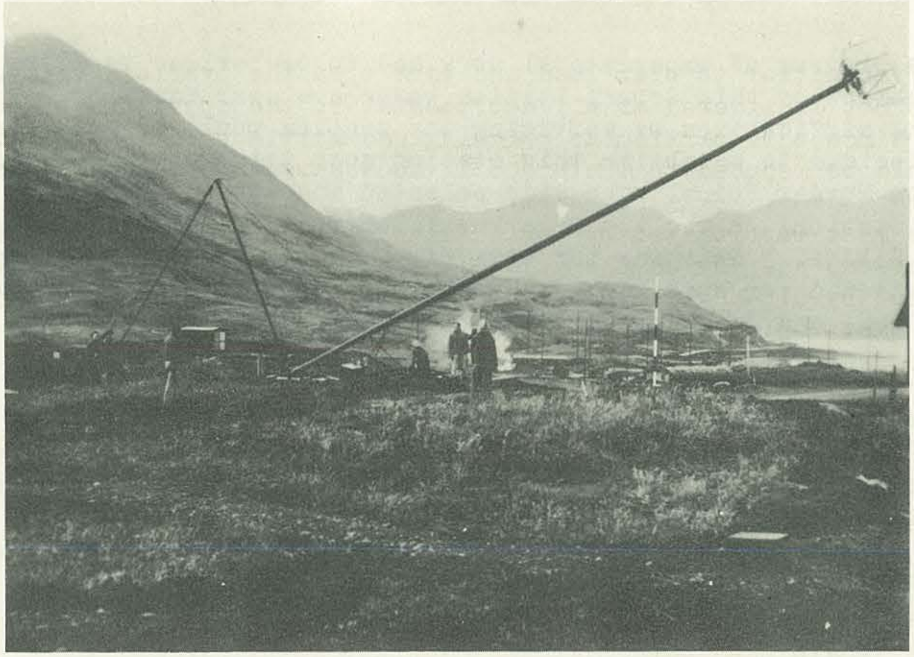


FIGURE 24.
MAST BEING RAISED (2).

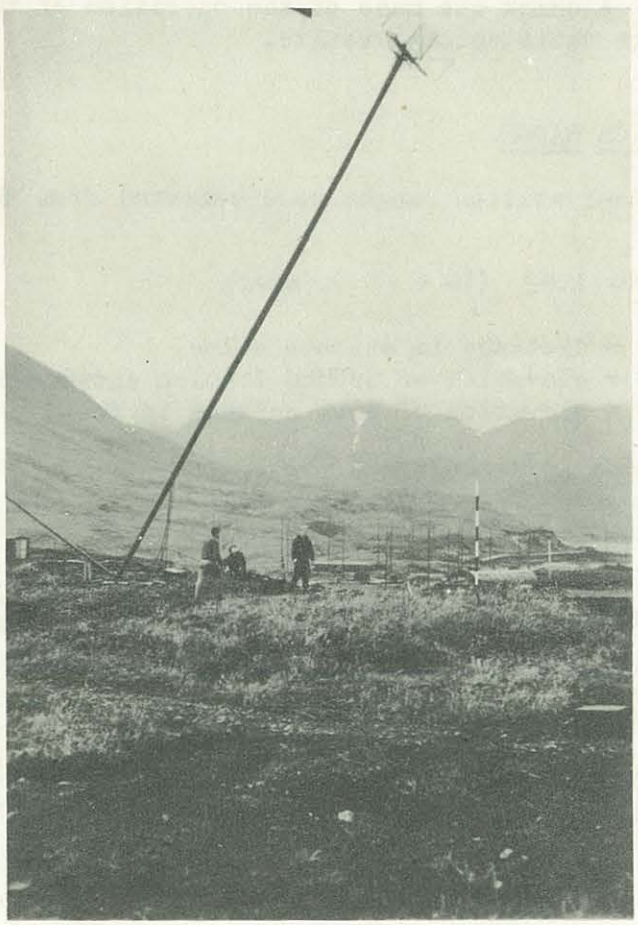


FIGURE 25. MAST BEING RAISED (3).

The program of experimental work had to be revised to allow the establishment of this Ground Station somewhere near Massacre Bay where the difficulties of servicing the station would be much less. It was decided to establish this station near triangulation Station LITTLE on Murder Point. The side selected was about a half mile west of this station, on the top of a knoll 105 feet in elevation near the Station SARANAC. This was the site of a gun emplacement which had been abandoned for some time. A small hut was available as quarters for the men, and as space in which to install the Ground Station equipment.

The erection of the mast followed much the same lines as at Station SHOR, with about four and a half hours total time required for erection. It was necessary to install aviation obstruction lights on the mast head, for the station was on the line of approach to the landing field. Power was made available from shore for these lights. The elevation of the dipoles was computed at 155 feet. A series of photographs showing phases in the erection of the mast are shown in Figs. 22 to 27.

The Receiver at this station was tuned to a frequency of 250 mcps, and the Transmitter checked at 310 mcps. The indicated power output at this station was about 50 watts average, or a peak per-signal power of 12 kilowatts. A check was made of the operation of this station with the Ship with satisfactory results.

THEORETICAL STATION RANGE.

The theoretical station ranges were computed from the following formula:

$$D = 1.42 \ (\sqrt{G} + \sqrt{S}), \text{ where}$$

D = distance in statute miles,
G = elevation of Ground Station antenna in feet;
S = elevation of Ship antenna in feet.

In this case:
G at station SHOR = 270 feet
G at station RAN = 155 feet
S at Ship = 80 feet

Therefore, the theoretical ranges of the two stations are

SHOR	36 statute miles
RAN	31 statute miles.

This formula actually gives values for relatively long lines, and does not give a true range for short lines. Therefore, it was

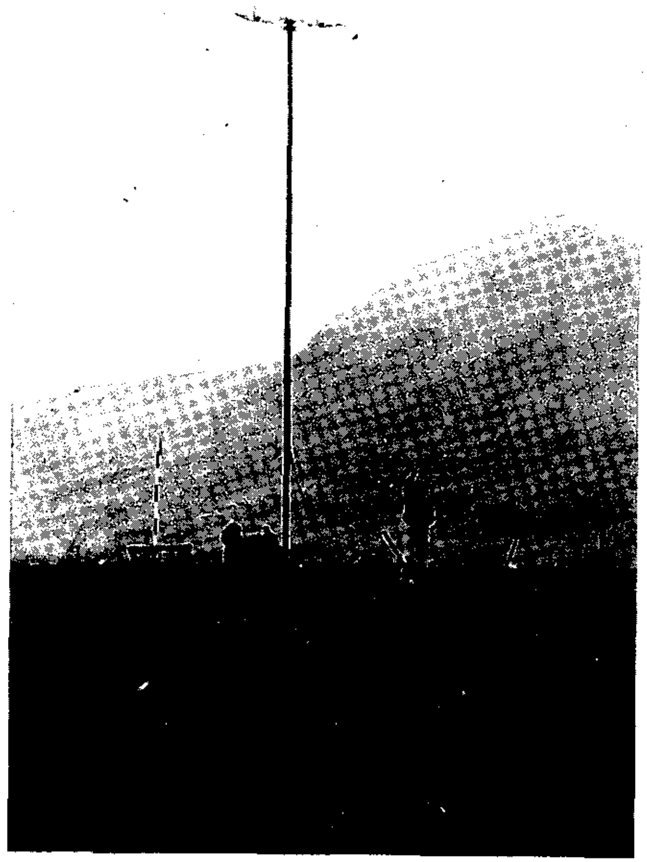


FIGURE 26. MAST BEING RAISED (3).

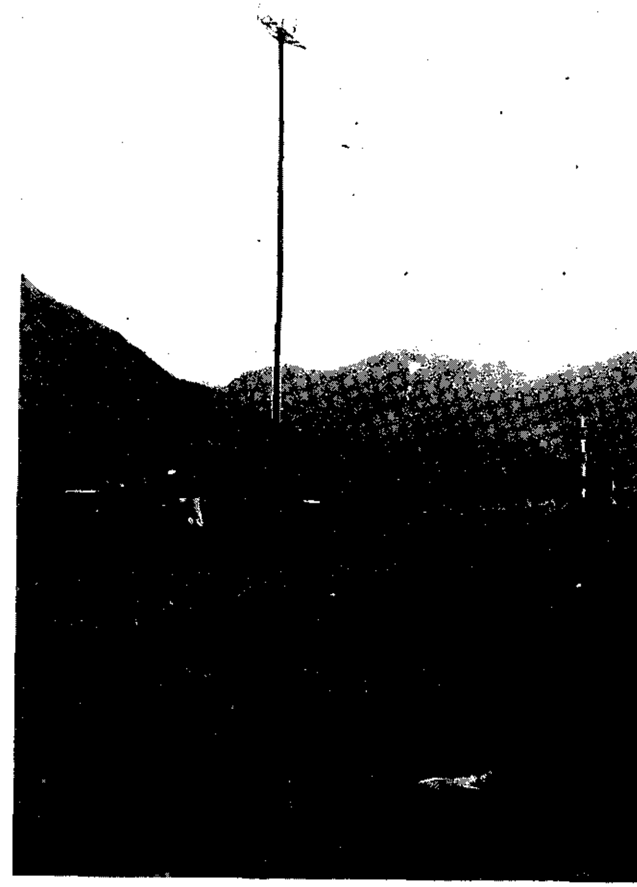


FIGURE 27. MAST ERECTED.

expected that the useful range would be somewhat greater than that computed. It was interesting to see how much further correct and useful mileage readings could be obtained.

PRELIMINARY OPERATION AND CALIBRATION.

Ground Station lag has been standardized at 0.180 statute miles; therefore, if there were no additional lag in the Ship Equipment, the vernier setting for correct distance measurement should be 99.820. However, the lengths of the antenna transmission lines and the interconnecting cable add an appreciable lag to the inherent instrument lag. This value can be computed from a theoretical consideration of the cable properties from the formula:

$$D = \frac{1}{5280} \times \frac{1}{2} \times \left(\frac{R + T}{0.65} + \frac{I - i}{0.50} \right)$$

Where D = additional correction in statute miles,
R = length of transmission line from dipole to Receiver in feet,
T = length of transmission line from dipole to Transmitter in feet,
I = length of interconnecting cable in feet,
i = length of interconnecting test cable.

In this installation:

R = 75 feet. I = 35 feet.
T = 75 feet. i = 5 feet.

From these values: D = 0.028 statute miles

And the vernier reading for the ZERO CHECK is

$$99.820 - 0.028 = 99.792.$$

Several preliminary checks with Station SHOR indicated that this correction was too much, that is, all distances were short by about 0.010 mile. Further, as this adjustment caused the Marker Pip to be moved a little too far clockwise for good results, the setting was made (arbitrarily) at 99.802. The first series of tests were with this setting, and with Station SHOR only in operation, and when there would be no interference with other field work.

A special plotting sheet was prepared, scale 1:80,000, on which to plot visual fixes taken simultaneously with SHORAN fixes. This scale was selected as most satisfactory since most distances to be measured would be of the order of thirty to fifty miles in length; and the scale was most practical for use of the three-arm protractor in plotting the visual fix. A series of 51 observations were made on 11 September with distances varying from 12.8 to 33.2 statute miles. The mean difference between SHORAN and scaled distances was found to be 0.006; that is, the SHORAN distances averaged 0.006 miles short of the scaled distance. Consequently the ZERO CHECK adjustment was made at 99.808.

A further series of test distances was made on 15 September. On this day, the observed distances varied from 8.7 to 40.2 statute miles. The mean difference as calculated from these observations indicated that 99.808 was too large by about 0.006, that is, the measured distances were longer by this amount than the scaled distances. But, as there were many shifts in fixes, not too much weight has been given this data, and the ZERO SET was adjusted at 99.806 and the adjustment not changed for the remainder of the operations.

It is not to be inferred from the above paragraphs that the plotting of the three point fix is exact, nor is the data from which it is obtained. Actual tests show that, where the angle between two objects is about 30°, and the distance from them is about 10 Nautical miles, that an error of 01' in the observed angle will displace the position about 10 meters; and where the distance is about 20 miles, this shift will be about 25 meters. If this angle is about 120°, the shift is smaller, being about 4 meters in 12 miles. As a result of this possible error in a three-point fix position, the differences above cannot indicate a true error, but can indicate only that the settings as prescribed in the manual are not exactly correct. They may indicate that the Ground Station lag is not as large as theoretical computations make it; it may be somewhat nearer 0.165 statute miles. It is also possible that no two Ground Stations will have exactly the same lag, a fact which is shown to be the case in the test work done on 29 September and 5 October 1945.

A source of a small error in Ground Station ZERO ADJUST is in the fixed and variable delay lines, and in the adjustment of this ZERO. The lines are made up of sections of artificial transmission lines with a computed delay time corresponding to 0.005 statute mile. It is apparent from the operation of the ZERO ADJUST that there are specific steps in the adjustment, and that it is only accidental that one point should make a perfect coincidence of the two pulses shown on the 'scope. It is more probable that the position should be somewhere in between two contacts, and that the combined error in the fixed and variable delay lines may be as much as + or - 0.005 mile (allowing half the error to each delay). This cannot be exactly compensated for in the present equipment, but the fact of the error should be known. To determine what the actual per-section value of the delay line was, a short test was run with one station in operation. The ship was secured alongside the pier, so there should be no change in actual distance. The ZERO ADJUST was properly set at the Ground Station, and the mileage read at the Ship. The ZERO ADJUST was moved one point to the right at a time until four settings had been made, a mileage reading being taken at each stting. The ZERO ADJUST was then properly set, and the mileage re-read:

ZERO ADJUST	DISTANCE
Correct	02.595
1 right (C W)	02.602
2 right	02.605
3 right	02.609
4 right	02.614
Correct	02.595

From this it would appear that each section of the variable delay line is close to the theoretical value (mean value 0.0048 statute mile). Thus, had a series of readings been taken, and then it was discovered that the ZERO ADJUST had not been correctly set, the proper correction could be applied: subtract 0.005 per point if the ZERO is to the right; add 0.005 per point if the ZERO is to the left. Or, add if it is necessary to turn the switch clockwise; subtract if turned counter-clockwise.

PROGRAM OF OPERATIONAL TESTS.

Due to the limited time available for experimentation with the SHORAN equipment, the following program was laid out with the view of accomplishing as much as possible with the least waste of time:

a- Run line between RAN-SHOR keeping on line by visual control. Pass out of Bay by East Channel. At Buoy 6 set course 98° true and continue eastward as far as practical, when, reverse course and repeat back to anchorage. Take SHORAN fix at one minute intervals throughout run. Take Visual fix at five minute intervals.

b- Pass out of Bay through West Channel. At point near sea buoy c/c to 180° true and run to Lat. 52° 34', when c/c to 90° true maintaining ship on this course for about 30 nautical miles, or to limit of reception of signals from Station RAN. Then c/c to make line spacing about 1 mile, and set course 270° true to limit of reception of signals from Station SHOR. Return to anchorage.

c- Run total of six (6) lines on east-west courses parallel and similar to (b).

d- Develop the area between Lat. 52° 34' to 52° 41' north, and Long. 173° 10' to 173° 21' east, by lines spaced at about 350 meters, as per standard practice for the area.

e- Repeat line (a), but with SHORAN fixes at 30-second intervals.

Prepare a standard 42" x 72" boat sheet on best available manila paper, plotting the two Stations SHOR and RAN only, and ink in the distance circles at 2 statute-mile spacing from each station to limit of the sheet. Suitable colors to be used for these arcs.

Use an ODESSEY Protractor to plot SHORAN fixes.

Take three-point fixes at not less than 10-minute intervals whenever possible.

In these operations a total of 525 statute miles were run, exclusive of the runs necessary to and from the Bay. Except for the two lines specified in (a) and (e), soundings were taken using the 808-AS type Depth Recorder, and all work recorded in a manner suitable for use in plotting a standard hydrographic survey. The Sheet was given the number 4245 EXPLORER, with Sounding Record Vols. 1, 2, 3, and 4. The over-all picture of the operations can be seen in Fig.32.

RESULTS OF THE EXPERIMENTAL WORK.

The two main objects in making these experiments were to determine the suitability of SHORAN in Hydrographic Surveys, and to check upon the accuracy and consistency of the observations. The experimental work clearly and conclusively demonstrated that SHORAN is a very valuable device with which to control this type of survey. The accuracy of the SHORAN fix and the speed with which it can be obtained and plotted are almost unbelievable. Changes of 1/2° in course show up easily with this control. Positions taken at uniform time intervals show uniform spacing on the sheet. A Position can be plotted within 15 seconds after the time of "MARK", and a new course set without loss of any time, if necessary. As a means of comparison (or contrast), visual fixes were taken simultaneously with SHORAN fixes. It required not less than 30 seconds to get the angles recorded, and an additional 30 to 45 seconds to plot the fix with the standard protractor, or between 4 to 6 times as much time as required to plot a SHORAN fix.

.005
4
.020

Since the velocity of the electromagnetic wave in space is constant within the limits set forth in the section on "HOW SHORAN WORKS", there is no need to make any adjustment to measured distances as was always found to be necessary in Radio Acoustic Ranging (R.A.R.). Further, the radio path is well defined over the relatively short distances measured, and is not subject to reflections within the useful distances; whereas, the path of sound in sea-water was little understood, though there were many theories on the effects of reflections from the surface and bottom, and the distortions caused by intervening shoals. Once the Instrumental ZERO had been determined, it is only necessary to correct for the deviation from this setting (which is usually small and most of the time, not plottable).

It is fairly conclusively shown that the Ground Station lag is somewhat smaller than the theoretical value of 0.180 statute mile, and that it is not necessarily the same for all Ground Station equipments. An exact value for each station has not been determined, but a very close approximation to the correct values are:

SHOR .... 0.163 statute miles;
RAN .... 0.149 statute miles;

and, as a consequence, the two ZERO SETTINGS on the Ship equipment should be:

SHOR 99.808,
RAN .... 99.822.

Further, it was discovered that the ZERO SET did not remain constant throughout a long period of operation, and that it was necessary to record the value of the ZERO CHECK as determined at frequent intervals in order to compensate for this drift. This was found to vary as much as 0.013 statute miles during an eight-hour period of operation; and that there was no apparent predictable rate of change. The curves of the six days' operations showing the ZERO drift are given in Figs. 30 and 31. A straight line connection of points would probably give a good approximation to this correction. In most cases it is very small, and, of course, can be neglected while plotting the boat sheet. This maximum deviation of 0.013 statute mile is about 20 meters.

The values for the ZERO SETS were determined from the three runs on the line between SHOR and RAN. The computed distance (by triangulation inverse) was found to be 66,600 meters, or 41.382 statute miles. The mean sum of 299 observations gives this distance as 41.364 statute miles. A comparison with visual fixes indicated that the correction to all readings should be about as follows:

SHOR .... +0.002 statute miles,
RAN .... +0.016 statute miles.

It is assumed in these computations that the distance between SHORAN is exactly 41.382 statute miles, which would require perfect triangulation. Further, the two positions are based on several schemes of second order triangulation covering several groups of islands, which have not been adjusted to a common base. Therefore, there may be an error of as much as 0.004 statute miles in this computed base even with the adjusted network. This argument holds as well with all the visual fixes taken simultaneously with the SHORAN fixes, and the differences between the SHORAN distances and these scaled from the plotting sheet are to be taken with some caution. Therefore, these differences can only indicate that there is actually some difference between theoretical and actual lag values, and not that the actual difference has been determined. These values are probably within a few thousandths of a statute mile of the correct value, and would be highly accurate for hydrographic survey control. This will be corroborated by experience which indicated that the positions can be plotted about as follows:

Scale of sheet: 1:80,000 to nearest 0.01 statute mile (16 meters);
Scale of sheet: 1:40,000 to nearest 0.005 statute mile (8 meters).

In determining the values for the distance differences, the three-point fixes were plotted as carefully as possible, then the distances to the two Ground Stations scaled off. These calues were then compared with the distances measured by SHORAN. A fix was rejected (in the comparisons) if the difference to even one station was excessive (say 100 meters).

The per-station 'error' is substantiated by the simultaneous fixes taken during the runs of lines (b), (c), and (d), but the values determined must be considered only a verification that this difference exists, and must also be considered in the light of a probable large error due to the three-point fix itself, since the observed angles can be assumed to be correct to + or - 01', and that signal position is not known within the tolerance of second (or even third) order triangulation.

A summary of these distance differences is given in the following table:

Date	Number of Comparisons	Mean Differences		ZERO SET 99.806	Table Number
29 Sept.	177	SHOR	+ 0.002		I & I-A
		RAN	+ 0.016		
1 Oct.	36	SHOR	+ 0.006		III
		RAN	+ 0.002		
2 Oct.	53	SHOR	+ 0.011		IV
		RAN	- 0.001		
3 Oct.	57	*SHOR	- 0.005		V
		*RAN	+ 0.017		

Date	Number of Comparisons	Mean Differences		ZERO SET 99.806	Table Number
5 Oct.	122	SHOR	+0.002		VI
		RAN	+0.016		

* The values determined on this day are considered almost as good as those of 29 Sept. and 5 Oct., as the signals for the fixes were the same throughout the day. There were too many changes in the fixes of the other days to attach very much weight to those values.

MAXIMUM DISTANCES OBTAINED.

The value of SHORAN would be very great indeed if the useful range of the equipment were sufficiently large for a moderate elevation of the Ground Stations. It was hoped that the Ground Stations could be established on relatively high ground so that the elevation of the top of the Mast would be at about 500 feet, when the theoretical distance would be about 43 statute miles. As conditions did not permit the desired elevation, the best sites available were used. As indicated in a previous paragraph the stations were established at a considerable lower elevation. The runs to determine the maximum useful range were made with the following results:

Date	Station	Theoretical Max. Distance	Practical Max. Distance	Excess over Theoretical
2 Oct.	SHOR	36 Statute Miles	47.335 Statute Miles	11.3 Statute Miles
5 Oct.	RAN	31 Statute Miles	46.953 Statute Miles	15.9 Statute Miles

Signals were excellent up to these distances, after which there was a very rapid decrease in signal strength, and within a mile, there was not enough to give an indication even with maximum gain. This large excess over that computed by formula is due largely to the much greater refractive effects at low altitudes and to a lesser degree by the great signal strength within the range used. It would appear that a safe formula for the computation of theoretical range with moderate elevation would be:

$$D = 2.0 \left(\sqrt{G} + \sqrt{S} \right), \text{ where } G \text{ will not exceed 500 feet.}$$

The fact that the signals from Station RAN were received at almost the same distance as those from SHOR which was at an elevation some 120 feet greater, may be accounted for by the fact that a much more experienced Technician was detailed to assist the assigned operator at this Station and observe the actual working conditions, and make such adjustments as seemed necessary. The station was therefore kept at optimum operating condition at all times, with receiver tuning checked frequently (and gain set) to assure proper reception of the ship's signals.

The MINIMUM distances measured were obtained when passing near Station RAN by West Pass. These varied from 1.010 to 1.005 statute miles, with gain at Zero to prevent over-saturation. In general, such short distances will not be used, but if they are, they will have to be corrected to sea-level distances as explained elsewhere. (This correction will not be much greater than 0.005 in the most extreme case, however.)

The Sketch shown in Fig. 32 will give a general idea of the work done during these experiments. The circled positions refer to those listed in the various tables, and are those for which there is a simultaneous SHORAN and visual fix. The other positions are those which were used for the hydrographic survey control, and are connected by means of the colored lines. As this sketch is for illustrative purposes only, distances cannot be scaled from it. The sketch was made from US C&GS Chart 8865, with a scale modification to about 1:160,000.

CASUALTIES.

Only one major casualty to the equipment occured during the total operating time (nearly seven days), during which the Ground Stations were operating nearly 9 hours a day. After about three hours operation of Station RAN on 1 October, the Operator advised the Ship that he had to shut down as smoke was coming from the Monitor Unit, and that there was no trace on the Cathode Ray tube. The fault was isolated to the Receiver Unit, where later examination showed that one of the coupling condensers in an IF transformer had shorted, causing all the filter resistors in the plate supply to burn out. This heavy load on the power supply tubes (2-5R4GY's) had been too great, and had burned them out as well. Replacement parts were "borrowed" from the spare Ship equipment and placed in the Ground Station Unit, after which a test run proved no other damage had been done.

It was noticed that there was considerable interference at Station RAN from some other RADAR equipment in the vicinity, and that the Receiver would block frequently from these pulses. There were no seriously unsatisfactory results from this blocking, and the station was operated three days on the original frequency. Checks showed that the RADAR frequency was about 246 mcps, so it was decided to shift the Station receiving frequency up about 5 mcps to 255 mcps, and this was done in the evening of 2 October. While blocking still continued, the effect was much diminished. This frequency was maintained during the balance of the tests. In changing the Ground Station Receiver frequency, it was also necessary to change the high frequency in the Ship Transmitter to correspond: this is about the upper limit in this setting.

The Power Units (PU-4) gave very little trouble during the time of operations. There were such minor casualties as: forgetting to turn on the gasoline supply line valve; and flooding of the engine by failure of the special pressure valve in the supply line. No actual stoppage of operations was caused by any power unit failure. However, a man who really understands two-cycle engines is really necessary at one of these Ground Stations.

As there is an excess of 24-volt d.c. power, this was utilized to charge batteries for the Radio 'Phone. In one instance, the batteries were left connected to the generator when it was shut down, with the result that the d.c. polarity of the generator was reversed, and the batteries dead. This reversal of polarity was remedied by flashing the field in the correct polarity with a new set of batteries.

GROUND STATION PERSONNEL AND OPERATION.

For the purposes of these experiments, the minimum of personnel was assigned to each of the Ground Stations: a Junior Radio Technician, and a Seaman, a.b., as assistant. This is the absolute minimum for station operation of about 8 hours a day. Where it is contemplated that operations will extend over longer periods, additional men must be available, as there is a large amount of routine checking to be done to keep the station in correct operating condition. In the installations where this equipment has been used by the ARMY, it has been the practice to have an Officer in charge, with three technicians, three assistants, and three or four men as Guards. This large group is not essential from the operating point of view: guards will not be required in the areas where surveys will be conducted; nor will it be necessary to detail an Officer to a Station. The Station complement should consist of (a) a Radio Technician, in charge; (b) a Radio man; and (c) at least two seamen as general assistants, if continuous operation of the Ground Station is contemplated.

Ground Station equipment must be started about 30 minutes before control operations are scheduled to begin, during which time the various functions must be checked frequently to assure proper operation. The routine checks as outlined in the Operators Manual should be followed implicitly at intervals no greater than one hour, and preferably at intervals of 30 minutes. Each series of checks requires about 5 minutes, and will not greatly interfere with operations from the Ship. The ZERO ADJUST is the most important, and if no other check is made, this one MUST be made frequently, and any great adjustment (say 2 points or more) reported immediately.

It is desirable to have the ZERO ADJUST checked at a specified time, for it is during this check that the Ship Unit can be properly CALIBRATED. Both stations can be on MONITOR-OPERATE at the same time, and a 5-minute period is sufficient to make the CALIBRATION ADJUSTMENT on the Ship equipment. Naturally, it is not generally possible to Calibrate to BOTH stations simultaneously, for the crystals will not necessarily be exactly alike: 93.109 kcs. It will be noticed that one pip will move slowly while the other is stationary. Ordinarily, this rotation speed will be not faster than about 2 or 3 revolutions per minute, and, in general, there will be a 1:100,000 check between the two stations. This check cannot be made before a 20- to 30-minute warm-up period of both Ground Station and Ship equipments.

The antenna reflector system confines the transmitted return pulses to a beam width of very nearly 80°. The effect is very pronounced as the side of the beam is approached, for the received signal becomes flickery and fuzzy, and it is hard to align the pulses with the Marker Pulse. A similar effect is observed at the Ground Station, for the received pulse (shown when the Function switch is in 'Operate' position). The effect is not so noticeable when the ship is within 20 to 30 miles of the Ground Station, but at greater distances, the antenna must be trained so that it points in the general direction of the Ship. In order to facilitate this operation, several orientation points were located at each station when it was set up, and stakes driven to which to orient the antenna array. These were numbered 1, 2, and 3 (and so on) for identification. As various areas were passed through by the ship, the operator at the Ground Station affected was requested to swing the antenna to the desired position. The operator can, and should, make such adjustments without the advice from the ship if, by observing the signals on his 'scope, there is an indication that the ship is passing out of the beam.

The Ground Station equipment must be operated for at least 30 minutes per day to keep it in optimum working condition. This will generate enough heat in the equipment to keep it dry; it will often permit the discovery of a fault at a time when there is an opportunity to correct it. All controls should be turned slightly to prevent 'freezing' in one position, and all adjustments should be made as though the station was to be in operation all day. The routine checks to the various blowers and other mechanical parts should be done as specified in the Manual. In general, the accumulation of dust in these areas is very small, but it should be guarded against.

The Power Units (PU-4), which are high speed 2-cycle gasoline engine drive generators, require a certain amount of attention to keep them ready for use at a minute's notice. The precautions relative to the quality of gasoline, lubricating oil, and even straining the gasoline must be followed or unnecessary delays will result. A man with experience with out-board motors is qualified to take care of these units. As there are two generators at each equipment, they should be used alternately as much as practicable.

It is desirable to keep a log at each Station, giving the Serial Numbers of each piece of equipment. This log should note the times of starting and stopping the equipment; what adjustments, other than routine, are necessary; the amount of gasoline used, and so on. It must be kept up-to-date at all times.

There is sufficient a.c. power available to provide about 150 watts of lighting, and d.c. power at 26-volts to keep storage batteries for communication equipment charged. If such a charging circuit is used, the batteries must be connected to the generator through suitable switches or relays so that the battery is connected in only when the generator is running. The relay will take care of this automatically, but a switch must be opened before the generator is stopped, and closed after the generator is started.

These Units are quite economical in the consumption of gasoline, This is an important factor in use of the equipment, for it is necessary to haul (or back-pack) all the gasoline to the station. It was found that, during these tests, about 3 quarts per hour was the average consumption at full load. Of course, this quantity will vary somewhat with the installation and operator. It would be safe to allow one gallon per hour of operation when setting up the station, and that quantity taken to the station when it is established, for the best transportation and conditions will probably obtain at that time.

<u>SHIP STATION AND PERSONNEL AND OPERATION.</u>

The personnel set-up in the Ship during these runs was as follows:

1- The Officer in Charge,
2- The Officer on Watch,
3- The Officer SHORAN Observer,
4- An Officer to take angles with No. 1, or No. 2,
5- The Recorder,
6- The Fathometer Reader,
7- The Quartermaster, and
8- The Helmsman.

The three Officers alternated duties at frequent intervals, usually hourly, so that all might have some experience at both SHORAN Observing, and SHORAN navigation. The SHORAN observing is not a laborious duty, but is somewhat fatiguing due to the necessity to watch the moving pulses and keep that nearly aligned at all times so as to be ready for a fix when called for.

The Recorder and the Fathometer Reader alternated duty at about the same frequency.

The Ship equipment must (or should be) started up some 20 to 30 minutes before work is to begin. This actual warm-up period is not so critical on the Ship as at the Ground Station, for the Ship equipment is Synchronized with the Ground Station, and this can be done frequently if it is necessary to shorten the warm-up period. During the warm-up period, the ZERO CHECK can be made; also a preliminary check can be made with the CAL ADJ. Since the accuracy of the timing of the Indicator depends upon the correct functioning of the 93.109 kcs. crystal, proper CAL ADJ cannot be made until a stable temperature has been reached - or in about 20 minutes. There will be a noticeable drift to this crystal frequency at first, but there will be little or no change after the warm-up period.

In these operations, the ZERO CHECK was set (Sept. 30) so that both verniers read 99.806, and this setting was not changed for the duration of the tests, so that there would be a common reference for all observations. It was noticed that this setting did not remain constant for any great length of time; and, as a consequence, a ZERO CHECK was recorded at intervals of about an hour. It was then possible to make corrections to all recorded distances to reduce them to a common ZERO. The high frequency station (RAN) ZERO varied more than did the low frequency station (SHOR):

SHOR	99.805 to 99.814	correction +0.001 to -0.008
RAN	99.793 to 99.807	correction +0.013 to -0.001

While running lines (a) and (e), distances from the two Ground Stations were recorded at 60-second and 30-second intervals respectively. While making the experimental hydrographic survey, positions were recorded at 3-minute intervals, with an occasional odd interval as necessary to change course. An interval-timer (Stromberg-Carlson type) was used to indicate the time for positions and soundings.

At about 30 seconds before the time of a position, the Recorded called: "On the next," when the SHORAN operator made a preliminary setting of the verniers. At 10 seconds before the position, the Recorder called: "Ten Seconds," and the Operator began tracking the received pulses with the Marker. On signal from the interval-timer, the motion to the verniers was stopped, and the Operator called out the distances.

Example:

Forty-one two eight seven (recorded as 09.276)

Trials were made to place the Ship on a required line by SHORAN coordinates alone, with good success, considering that the exact transfer distances of the ship were not too well known. Turns were made with various degree of rudder angle from which a general idea of the transfer distances was given. A further study of this would be of great value when actual work is undertaken.

In order to place the Ship in a desired position to start a line, the SHORAN coordinates of the point were given the Observer, who then gave such directions as necessary to bring the Ship as near that point as possible. The process is simplest when going to or away from one station, and on a distance arc from the other one. With the transfer distance of the ship known, the Ship can be placed within a very small error of the desired position.

A sounding line was run along the bisector of the base line between the two stations on the 5th of October. The line started on the base line about 9 miles from RAN, course 98° true. The transfer distance was assumed to be 0.120 miles, and the turn started at a point near the center of the base $\frac{(41.363)}{2} - 0.120 = 20.562$.

The turn was a little wide, and the effect of the current not sufficiently allowed for, so the first four or five positions were not on the line. However, since the sum of the two distances on the first position should nearly equal the length of the base as this position was only 0.10 mile off the base, the position was well established, and a suitable course change made. As plotting is difficult near the base line, positions cannot be plotted at once, but after about 10 minutes' run, the arc intersection becomes good enough to plot quite easily, and then it is easy to back-plot the other positions. (In general, this process was not successful in R.A.R., for seldom did the sum distances on the base line check that length: They were too long or too short by an appreciable amount, varying from day to day.) SHORAN positions taken at uniform time intervals assist materially in the areas of very large or small angle of arc intersections.

For the greater part of the work done in these tests, the arc intersection varied from about 85° minimum to the southward of each Ground Station to about 120° maximum in the central portion of the area covered - not including the portion very near the base line. As brought out in another place, good fixes are obtainable where the arc intersection angle lay between 30° and 150°. As a general thing, this ideal is quite easily attained, except in the cases where the area to be covered crosses the base line between the two stations.

In running the line between the two Ground Stations, it was observed that the sum distances varied somewhat about a mean value, the variation not being too well defined. It must be remembered that there is no perfect piece of equipment, and that a small error in the linearity of the Goniometers will cause variations in measured distances

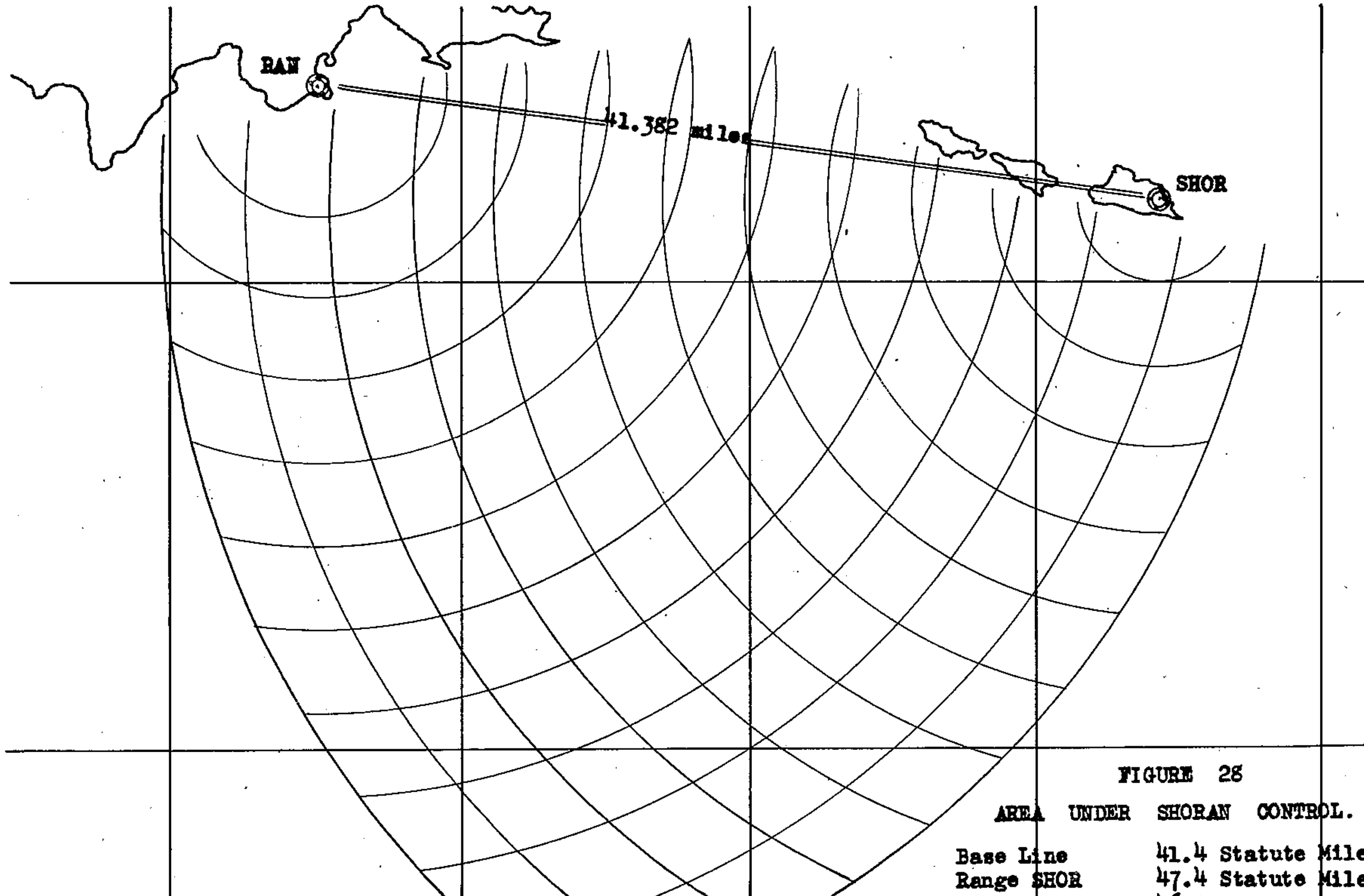
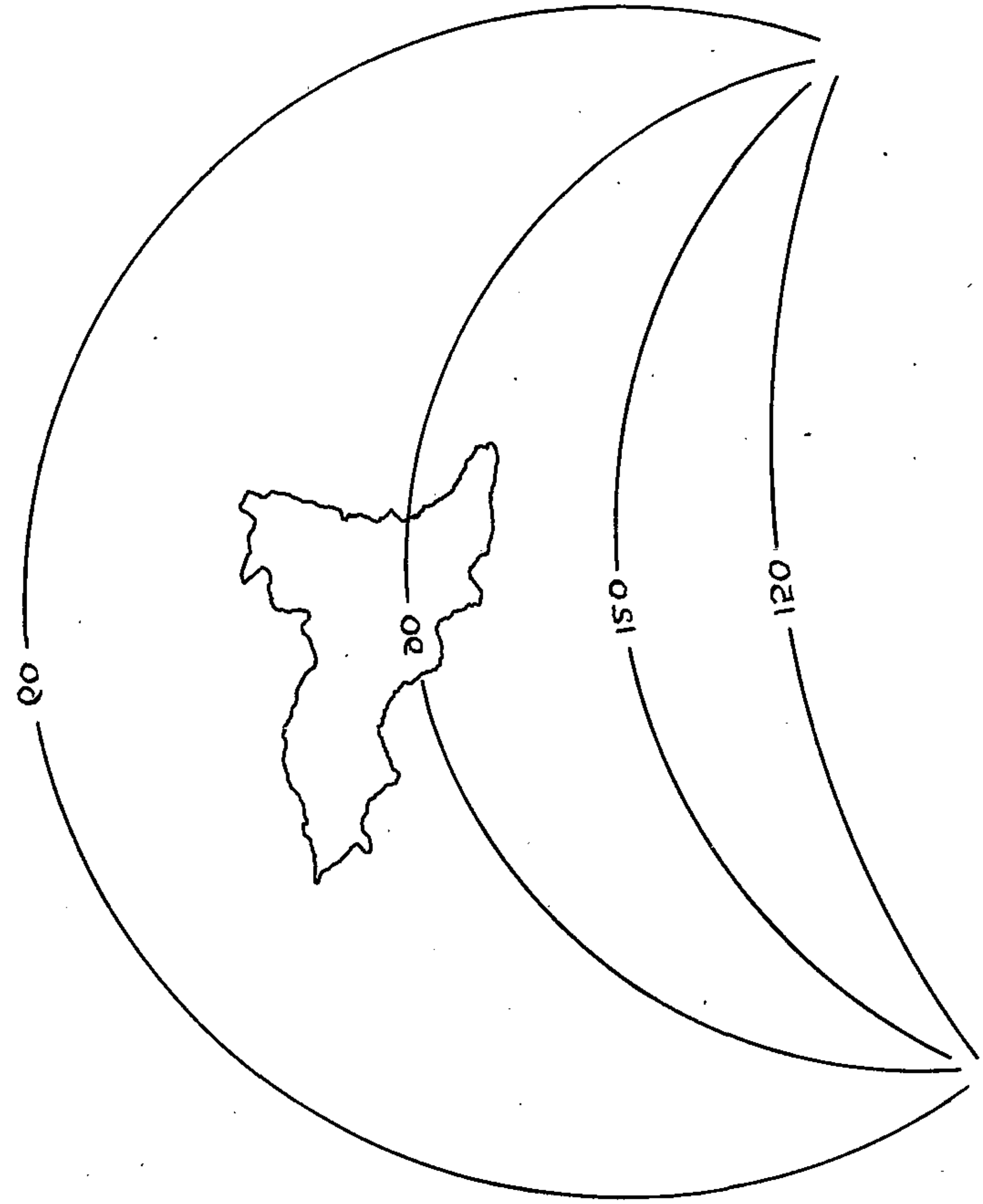


FIGURE 28

AREA UNDER SHORAN CONTROL.

Base Line	41.4 Statute Miles
Range SHOR	47.4 Statute Miles
Range RAN	46.9 Statute Miles
AREA	1250 Sqaure Miles.


60
90
150
120

depending upon the particular portion of the Goniometer coming into use at that time. A 4° error in linearity will cause an error in distance of about 0.010 mile. It is quite possible that the structural inaccuracies of the Goniometers may be as large as 2 degrees. This can be checked only by laboratory devised methods, and is not easily done in the field.

SELECTION OF SITES FOR GROUND STATIONS.

The location of the Ground Stations is of great importance where adequate control for Hydrographic Surveys is concerned. Sites should be selected which will:

1- afford an unobstructed "view" of the entire area to be covered;
2- be, if possible, within radio line-of-sight of each other for this will permit frequent checks on the over-all operational accuracy;
3- be accessible without undue difficulty in any weather; and
4- afford a means of extending the control beyond that already existing.

The greater the elevation of the site selected, the greater will be the range; but the economy of establishing a station at greater elevations than 500 feet is doubtful, when it is considered that the gain in distance is relatively small, and that the labor involved is much greater. With the useful range of 45 to 50 miles which is proven possible with elevations of about 300 feet, it appears that this elevation, or possibly 500 feet, might be the economical practical maximum elevation at which to establish a Station. It will be necessary to service a Ground Station sometimes when the weather is bad, and so, good access to the station is imperative. A site of suitable elevation, difficult to build on, which is easily accessible in most any weather will prove more useful than one where building is easy, but accessibility poor.

The best control of a given area where it is desired to go as far off-shore as possible, will be found where the Ground Stations are roughly 7/10 the range of the equipments apart. This is illustrated in the Sketch in Fig. 28, which uses the positions of SHOR and RAN as in the tests. Here the distance is about 41 miles - about 8/10 of the range. It can be seen that the coverage (by adequate control) is some 25 miles directly south of each Station, but that this area is limited by the range of the equipments. This coverage would be suitable where only two stations can be used - or where it is necessary to cover as much area as possible with the fewest stations.

In the Sketch in Fig. 29, the same over-all ranges are used, but Station SHOR has been assumed to be moved to position of Station NIZ, with a base line of about 32 miles, about 7/10 the range. Here,

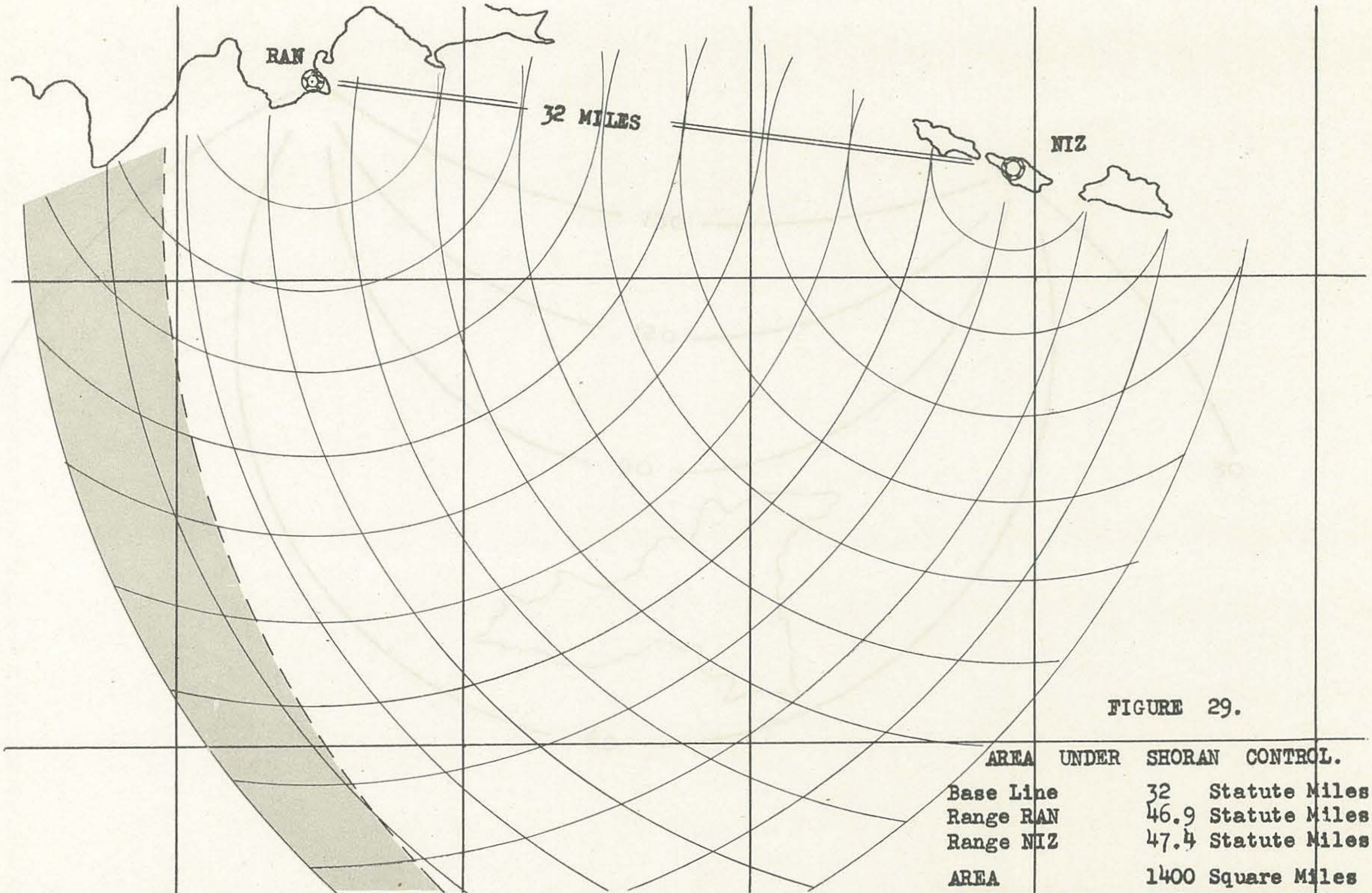
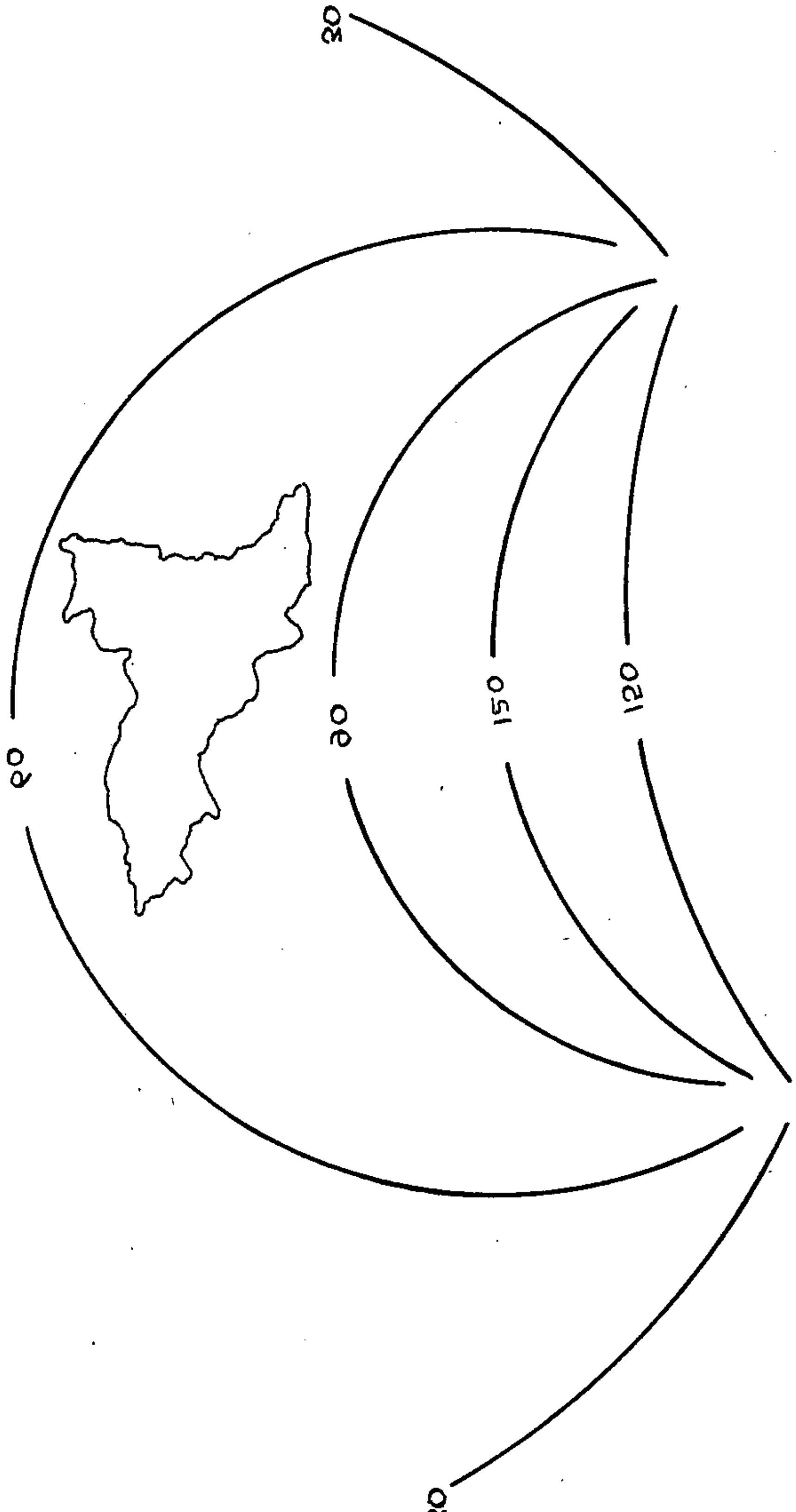


FIGURE 29.

AREA UNDER SHORAN CONTROL.

Base Line	32	Statute Miles
Range RAN	46.9	Statute Miles
Range NIZ	47.4	Statute Miles
AREA	1400	Square Miles
TINTED AREA	150	Square Miles.


30
60
90
150
120
30

it is seen - shown by the red shading - that the area covered is appreciably larger, this difference being about 150 square miles. The area does not extend much further off shore, but does extend over a longer shore-line. Stations at intervals of about 35 to 40 miles will probably give the most economical and adequate control. Of course, the actual "lay of the land" will determine the selection of the Stations sites, but the lengths of bases should be kept near these limits if possible.

MODIFICATIONS TO PRESENT INSTALLATIONS.

There is only one modification to the present installation in this Ship required at this time to make a more nearly perfectly operating equipment. The ship antenna system will have to be revised to assure best results on all headings of the ship. Considering that the present installation of the antenna base was somewhat make-shift, the results were very good. Material was not available at the time of installation to give sufficient spread between the transmitting and receiving dipoles; and the various appurtenances of the mast and RADAR acted as shields between the particular dipole and the Ground Station, thus cutting off all signals on certain headings. This effect was particularly noticeable on a north or south heading in the area to the southward of Station RAN, where the distances from SHOR were of the order of 40 miles. This will account for the fact that the courses were shaped so as to obtain signals from both stations in this area: that is, the course desired was 180° true, but it was necessary to steer 190° true to get a fix. Similarly, instead of steering 000°, it was necessary to set the course as 350° or 030° true. This 40° accounts for the coverage by the mast stays and the RADAR cage. An out-rigger type of antenna support has been devised which will permit swinging the antenna so as to clear these obstructions regardless of the heading the ship may be on.

The ground Station installations are very satisfactory. While the antenna mast showed itself well designed and stayed, there was some cause for uneasiness during the heavy winds which often occur in this area. A maximum wind velocity of about 65 miles per hour was felt several times (at SHOR). It is considered advisable to make an additional set of top-stays, with a greater spread at the base, since there is a weight of about 90 pounds concentrated in the antenna base and reflectors - at the mast head. The present stays are anchored at a distance of 20 feet from the base; the additional set should have a spread of 30 to 35 feet to give greater stability to the mast.

DISMANTLING THE GROUND STATIONS.

The Ground Stations were dismantled immediately on the conclusion of the field tests. Station RAN was dismantled during a heavy gale and a driving rain, in about 5 hours total time, including transporting the equipment to the Ship. The strong wind made it a little difficult to lower the mast, but this was accomplished between gusts, and without incident.

Good weather prevailed during the dismantling of Station SHOR, and the entire work was accomplished in about eight hours. The longer time was required by the necessity of transporting equipment to the beach, thence by boat, to the Ship.

THE PLOTTING SHEET.

The survey conducted with SHORAN control was plotted on a standard sized- 42" x 72"- boat sheet on a scale of 1:40,000. Only the two Ground Sattions SHOR and RAN were plotted on the sheet. Circular arcs of distance were scribed from each station, the interval between arcs being two (2) miles - 3218.70 meters.

For detailed hydrographic surveys, this scale is large enough for the ususal close developement desired. The area covered by a sheet of this size is about 45 miles in length and about 32 miles in width. In order to use SHORAN control to its limit, the off-shore surveys can be accomplished on a smaller scale- 1:80,000.

The boat sheet should be laid out so that the Ground Stations will be close to one of the sides of the sheet. As soon as the Stations are plotted, the distance arcs should be drawn in in appropriate colors, to cover the entire area. The practical spacing of these arcs will be 2 miles in most cases, but other spacing can be used. These arcs should be drawn in as soon as possible after the Stations have been plotted so that any distortion developing in the paper will be compensated for while the sheet is being prepared.

Large scale sections of plotting sheets can be prepared and scribed with appropriate distance arcs without the necessity of having the stations on the sheet in a manner similar to that used for far- offshore sheets for three-point fixes. The difference is that the arcs represent constant distances from the Stations on the one sheet, while they are arcs of constant angle between two stations on the other.

The ODESSEY Protractor is the most convenient "tool" to use in plotting the SHORAN fix. This Protractor is made of a piece of transparent plastic about 1/16" thick, and about 9" square for a 1:40,000 scale, and about 6" square for a 1:80,000 scale. Circles of 1-mile and 2-mile radius are scribed in heavy lines on the plastic from a common center. The spaces between these circles are then subdivided into tenths (0.1) miles with lighter lines. A small hole to accomodate a needle point is then drilled at the center.

Thus, the intervals between the 2-mile arcs on the sheet can be

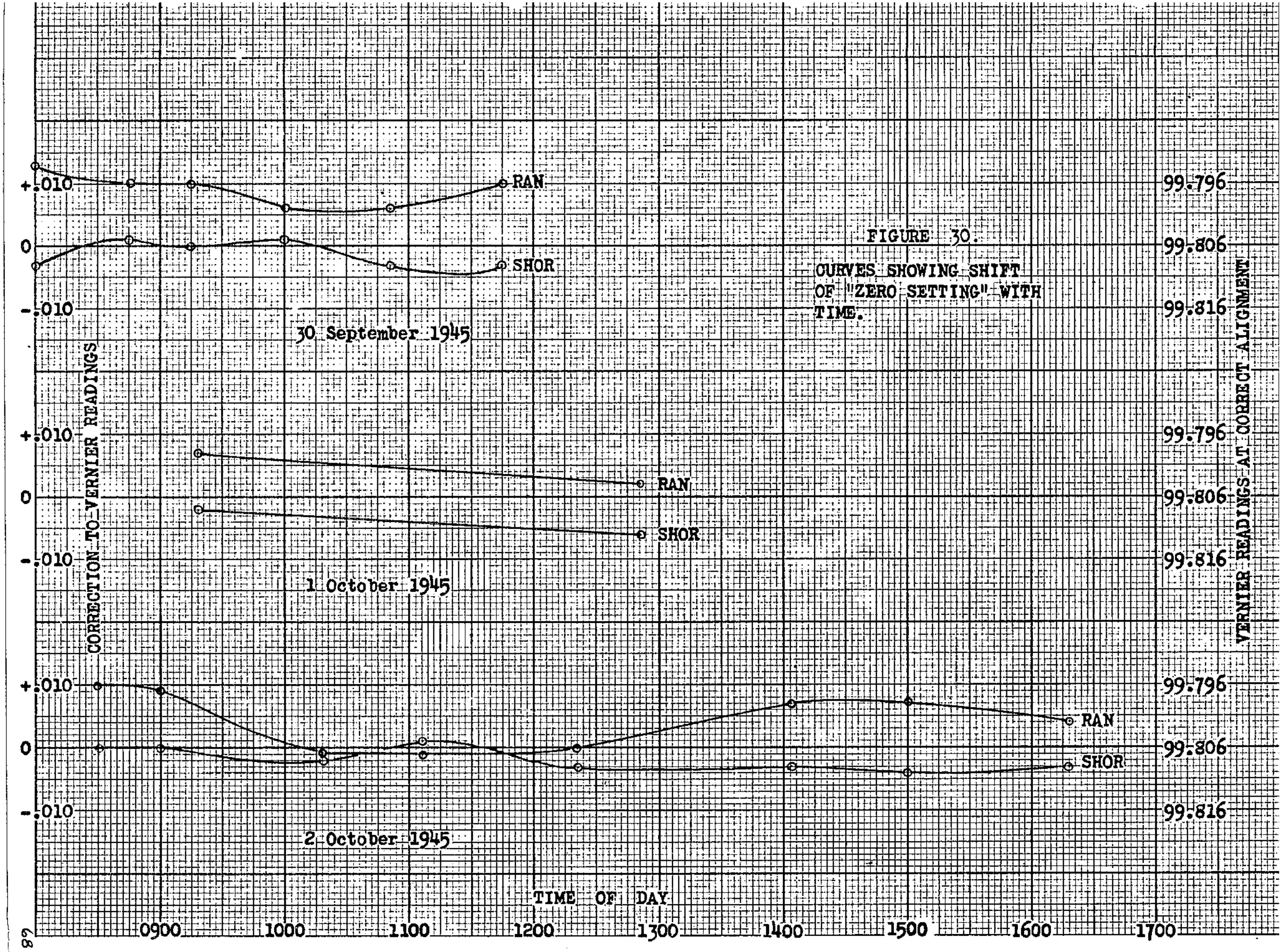


FIGURE 30.

CURVES SHOWING SHIFT OF "ZERO SETTING" WITH TIME.

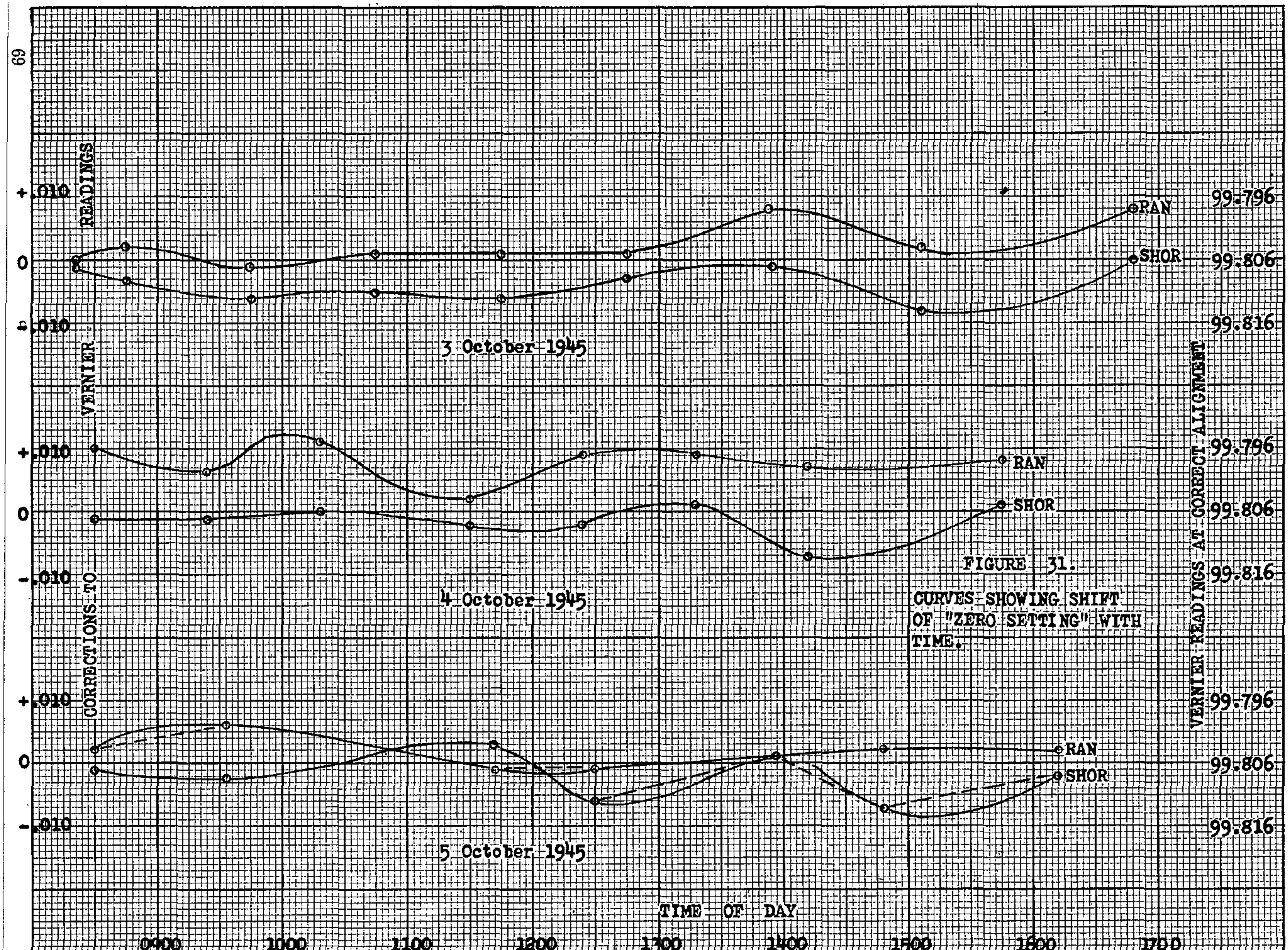


FIGURE 31.

CURVES SHOWING SHIFT OF "ZERO SETTING" WITH TIME.

subdivided directly into 0.1 miles, and by estimation, into 0.001 miles, by a process of selecting the desired division, placing that interval on the protractor tangent to the appropriate circular arc on the sheet, and pricking through the Protractor center. A pair of distances from the two Ground Stations can be plotted almost simultaneously with a little experience.

SUMMARY.

SHORAN is an ideal system for the control of hydrographic surveys. Some of its advantages may be summarized briefly as follows:

I--- The potential accuracy of this system is such that any distance can be measured with a probable error less than 5 meters, regardless of the length of the line. Positions as determined by the intersections of two simultaneous distance arcs will have an accuracy better than 15 meters in the area where the angle of intersection is greater than 30° and less than 150°. SHORAN Ground Stations can be located accurately by triangulation. Two or three such Stations will control a large area, and the survey will be completely homogeneous within itself.

The accuracy of the three-point fix obtained by sextant angles is dependent upon the relative size of the angles and the distance from the signals. Assuming the possibility of only 01' error in an angle (or both angles), the position error will be about 10 meters at ten miles when both angles are near 30°; and it will be about 25 miles at a distance of 20 miles with similar angles. This error becomes less as the angles are larger: an error of about 4 meters will exist when the angles become 120° and the distance about 12 miles. Smaller angles than 30° are ofter necessary in survey work only 10 miles off-shore. Further, another great source of error in the three-point fix is the indefiniteness of the signals, and the difficulty of seeing them as the distance is increased.

The range of the system is such as to permit very accurate surveys in areas as far off-shore as 40 to 50 miles depending upon the selection of the sites for the Ground Stations. With three Stations more or less on a straight line, and separeted by 35 to 40 miles, the area under good control will be about 100 miles in length along the axis (base lines) and at least 45 miles in width on one side of the base. If the Ground Stations are strategically located, this area may extend about 45 miles on each side of the axis.

The rapidity at which SHORAN fixes can be obtained and plotted practically precludes the use of other methods of control. A SHORAN fix can be obtained and plotted within 15 seconds, and fixes can be taken at intervals as small as 30 seconds without difficulty. In contrast, a sextant fix requires about 15 or 20 seconds to call out and have the angles recorded; almost the same time to lay them off on the protractor; then, a varying time up to 30 seconds to plot the fix.

With this possibility of frequent fixes, the areas where the fixes are indeterminate (arc intersection angles greater than about 150°, near the base line) can be accurately controlled if the time interval between the fixes is held constant.

The availability of the SHORAN fix at any instant permits the close development of any critical areas as far off shore as the range of the equipment with an accuracy greater than any method now in use.

II--- The velocity of radio waves through free space is almost constant under any conditions likely to be met with in hydrographic surveys. Thus, the sum of the two SHORAN distances measured ON the base line will always equal the length of the base; therefore, this system can be used as a means of extending control in advance of triangulation- or to supplement triangulation by measuring long lines.

This constancy of the velocity of radio waves precludes the necessity of laborious computations of corrections which are necessary with the R. A. R. method of control, in which the characteristics of the water- salinity, temperature, depth, and so on, effect materially the velocity of the sound wave through it. Further, for the short distances used, the radio wave can be considered as without any reflections whatsoever. This certainly cannot be said of the sound wave in water.

The effectiveness of the equipment is not at all impaired by weather conditions. It will operate as efficiently in rain or fog or darkness as it will in fine weather. The effects of static are negligible, if noticeable. Man-made static or interference has no detrimental effects on the operation of the system.

III-- A Ground Station equipment may be installed in a ship, and that ship act as a Station. This would be advantageous in carrying control into an area where the land control has been reduced to one Station, as, for example, at Cape Wrangell on the western end of Attu Island.

IV-- The selection of suitable Ground Station sites is of greatest importance to the effectiveness of the operation of the system. The time required to install the Ground Station is relatively long, and will depend largely upon the elevation of the station and the transportation available. Extra time spent in the original installation will be worth while in the long run, for the station MUST operate satisfactorily, and will probably be in use for several months.

TABLE OF SIZES AND WEIGHTS

Equipment name	Height inches	Width inches	Depth inches	Weight pounds	Remarks
Transmitter T-11/APN-3	20 1/2	19 3/4	22 1/2	106	
Indicator ID-17/APN-3	14 1/2	17 5/8	24 1/4	77	Receiver R-15/APN-3 included in Indicator
Transmitter T-12/CPN-2	40 1/2	25 1/4	20	209	
Monitor ID-17/CPN-2	21 1/2	25 1/4	20	98	Receiver R-15/APN-3 included in Monitor
Antennas and Transmission Lines	21 1/2	25 1/4	20	60	
Antenna Base	8	150	20	50	
Reflectors	36	50	4	20	Mast telescopes into 2 sections with 1/2 boom in each section
Mast	8	144		90	
Mast Accessories				255	
Power Units PU-4/CPN-2	17	35	21	140	2 Units per set
Power unit Accessories				64	2 units per set

A GOOD hut is necessary to house the equipment and as quarters for the personnel required to man the Station.

The Station personnel must be adequate to operate the station under the longest continuous periods considered. This personnel should consist of the following:

A Junior Radio Technician, in Charge, and
Three or four Seamen.

One of the Seames should be a man interested in radio so that he can assist the Technician and relieve him; one Seaman should be versed in the operation of a 2-cycle gasoline engine, for the heart of the Ground Station is this engine which drives the generator. The fourth man can take care of the general camp requirements.

V-- The use of SHORAN will permit the best utilization of weather in combined operations. Weather that is most suitable for triangulation can be used for that work; topography and launch hydrography can be prosecuted at this time under the most favorable conditions. During periods of fog or rain, off-shore ship hydrography with SHORAN control can be prosecuted to advantage. This will thus obviate the necessity of using good triangulation and inshore work weather for surveying in areas which would formerly require the same good weather for the visual fixes.

VI-- There are certain routine observations which must be made to insure proper operation of the SHORAN equipment:

A- In the Ship Equipment:

a- Make and record frequent ZERO CHECKS so that the shift in the ZERO SET can be known at all times;

b- Make a CAL ADJUST at least once an hour;

c- Check Transmitter frequencies at least once a week.

B- In the Ground Station Equipment:

a- Make routine operational checks at least once an hour;

b- Operate equipment on Monitor-Operate position for period to coincide with A-b above;

c- Keep Ship informed of changes in ZERO ADJ settings.

C- All equipment- both Ship and Ground Station- must be operated a short p eriod daily to insure that it is in good condition and to minimize delays.

VII-- Certain casualties are inevitable. Equipment will be rendered useless by faulty elements, short circuits, burned-out vacuum tubes, and so on. To guard against delays of this sort, each piece of equipment should be in duplicate so that a minimum of time will be required to put a station back on the air if one set has failed. It will not always be possible to land at a Station to make hurry-up repairs: the stand-by equipment will reduce loss of survey time to a minimum. Further, the actual length of time over which a specific equipment will operate continuously is not well known. Periods of 9 hours have been successful; and it is possible that longer than this is practical. However, with two equipments, it will be possible to alternate equipments in a manner similar to the generator units.

Respectfully submitted

Clarence A. Burmister
Lieutenant Commander
U S C & G S

Approved:

Roland D. Horne

Roland D. Horne
Commander, USC & GS
Commanding Ship EXPLORER.

PMOD	Physikalisch-Meteorologisches Observatorium Davos (World Radiation Center)
PMT	photomultipier tube
PSC	Polar stratospheric cloud
PSP	precision sunphotometer
P^3	Portable Pressurizer Pack (air sampler)
QBO	quasi-biennial oscillation
RITS	Radiatively Important Trace Species
RSD	residual standard deviation
SAGA	Soviet-American Gas and Aerosol Experiment
SAGE	Stratospheric Aerosol and Gas Experiment
SASP	Surface Air Sampling Program
SBUV	solar backscattered ultraviolet (satellite ozone instrument)
SCS	Soil Conservation Service, Anchorage, Alaska
SEAREX	Sea-Air Exchange Experiment
SEASPAN	SEAREX South Pacific Aerosol Network
SERI	Solar Energy Research Institute
SEY	Mahé Island, Seychelles
SIO	Scripps Institution of Oceanography
SMO	Samoa Observatory, American Samoa (CMDL)
SOI	Southern Oscillation Index
SOLRAD	Solar Radiation
SPO	South Pole Observatory, Antarctica (CMDL)
SRF	spectral response function
SRM	standard reference material
SSL	slightly stable layer
SST	sea-surface temperature
TECO	Thermal Electron Company
TEM	transmission electron microscope
TOGA	Tropical Ocean Global Atmosphere
TOMS	Total Ozone Mapping Spectrometer
TSI	Thermo Systems Incorporated
TSL	Technical Services Laboratory
TSP	total suspended particulate
UCI	University of California, Irvine
UPS	uninteruptable power supply
URAS	[a commercial CO_2 analyzer]
URI	University of Rhode Island
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UT	universal time
UV	ultraviolet
UVB	ultraviolet B spectral band
WHOI	Woods Hole Oceanographic Institute
WOCE	World Ocean Circulation Experiment
WMO	World Meteorological Organization
WPL	Wave Propagation Laboratory, Boulder, Colorado (ERL)

*U.S. GOVERNMENT PRINTING OFFICE: 1993-774-025/69048

TABLE A COMPUTATION OF STATION ERROR FOR STATION "SHOR"
ZERO SET 99.802 11 September 1945

POSITION	SHORAN DISTANCE Statute Miles	Meters (3)	SCALED Meters (4)	(4 - 3)
1	30.523	49122	49169	+ 47
2	28.716	46214	46217	+ 3
3	27.144	43684	43634	- 50
4	26,175	42125	42128	+ 3
5	25.543	41108	40985	- 23
6	24.640	39654	39668	+ 14
7	23.749	38293	38224	- 69
8	23.023	37052	37068	+ 16
9	22.250	35808	35826	+ 18
10	21.562	34701	34708	+ 7
11	20.909	33650	33640	- 10
12	20.276	32631	32640	+ 9
13	19.672	31659	31704	+ 45
14	19.136	30796	30844	+ 48
15	18.545	29845	29860	+ 15
16	18.144	29200	29216	+ 16
17	17.782	28617	28628	+ 11
18	17.489	28146	28132	+ 14
19	17.322	27893	27904	+ 11
20	18.160	29226	29248	+ 18
21	18.916	30443	30456	+ 13
22	20.096	32298	32344	+ 46
23	21.326	34321	32320	- 1
24	20.192	32496	32440	- 56
25	19.012	30597	30544	- 53
26	17.866	28753	28708	- 45
27	16.652	26799	26772	- 27
28	15.550	25025	25052	+ 27
29	14.402	23179	23132	- 47
30	12.972	20876	20848	- 28
31	12.781	20569	20608	+ 39
32	12.866	20706	20716	+ 10
33	13.046	20996	21028	+ 32
34	13.352	21488	21496	+ 8
35	13.738	22104	22116	+ 12
36	14.255	22941	22944	+ 3
37	14.742	23725	23744	+ 19
38	15.334	24678	24704	+ 26
39	16.128	25956	25948	- 8
40	16.746	26950	26988	+ 38
41	17.466	28109	28112	+ 3
42	18.286	29429	29488	+ 59
43	19.155	30827	30912	+ 85
44	20.060	32283	32320	+ 37
45	21.006	33896	33800	- 6
46	21.946	35318	35320	+ 2
47	22.912	36873	36896	+ 23
48	23.914	38486	38496	+ 10
49	25.108	40408	40424	+ 16
50	25.960	41779	41800	+ 21

TABLE A (Concluded)

POSITION	SHORAN DISTANCE Statute Miles	Meters (3)	SCALED Meters (4)	(4 - 3)
51	27.128	43658	43700	+ 42
52	28.360	45641	45680	+ 39
53	29.559	47571	47600	+ 29
54	31.018	49919	49960	+ 41
55	32.000	51499	51508	+ 9
56	33.200	53430	53448	+ 18

Mean Difference in Meters . . . + 10

Mean Difference in Statute Miles . . . . +0.006

Therefore the SERO SET should be at

99.802
\+ .006

New ZERO SET 99.808

TABLE B COMPUTATION OF STATION ERROR FOR STATION "SHOR"

ZERO SET 99.808 14 September 1945

POSITION	SHORAN DISTANCE Statute Miles	SHORAN DISTANCE Meters (3)	SCALED Meters (4)	(4 - 3)
1	36.996	59540	59552	+ 12
2	37.224	59906	59920	+ 14
3	37.460	60286	60296	+ 10
4	38.178	61442	61456	+ 14
5	38.481	61930	61936	+ 6
6	38.737	62342	62328	- 14
7	39.781	64022	64024	+ 2
8	40.245	64768	64782	+ 14
9	40.473	65135	65104	- 31
10	40.748	65578	65560	- 18
11	x			
12	38.457	61891	61920	+ 29
13	37.369	60140	60144	+ 4
14	36.308	58432	58440	+ 8
15	35.137	56548	56776	(+228)**
16	33.437	53812	53744	- 68
17	32.760	52722	52696	- 26
18	31.885	51314	51264	- 50
19	30.774	49526	49480	- 46
20	29.995	48272	48200	- 72
21	29.389	47298	47360	+ 62
22	29.079	46799	46840	+ 41
23	29.497	47471	47456	- 15
24	x			
25	25.480	41006	40962	- 44
26	22.501	36212	36200	- 12
27	21.275	34239	34232	- 7
28	19.947	32102	32064	- 38
29	18.798	30250	30240	- 10
30	17.719	28516	28496	- 20
31.	16.520	26587	26576	- 11
32	15.349	24702	24696	- 6
33	14.065	22636	22640	+ 4
34	12.983	20894	20904	+ 10
35	11.895	19143	19136	- 7

TABLE I COMPUTATION OF SHORAN CORRECTION FACTORS
Line (a) 29 September 1945

POSITION AND TIME		DISTANCE STATUTE MILES SHOR	RAN	SUM
1	0829	35.422	05.939	41.361
2	0830	35.201	01.152	41.354
3	0831	34.975	06.381	41.356
4	0832	34.763	06.604	41.368
5	0833	34.539	06.826	41.365
10	0844	32.115	09.246	41.361
11	0845	31.897	09.468	41.365
12	0846	31.641	09.724	41.365
13	0847	31.447	09.915	41.362
14	0848	31.228	10.133	41.361
15	0849	31.012	10.352	41.364
16	0850	30.806	10.566	41.372
17	0851	30.581	10.788	41.369
18	0852	30.256	11.015	41.371
19	0853	30.151	11.219	41.370
20	0854	29.933	11.436	41.369
21	0855	29.719	11.651	41.370
22	0856	29.501	11.867	41.368
23	0859	29.286	12.076	41.362
24	0858	29.076	12.292	41.368
25	0858	28.871	12.500	41.371
26	0900	28.658	12.712	41.370
27	0901	28.435	12.933	41.368
28	0902	28.228	13.138	41.366
29	0903	28.006	13.358	41.364
30	0904	27.804	13.567	41.371
31	0905	27.585	13.788	41.373
32	0906	27.378	13.988	41.366
33	0907	27.165	14.205	41.370

POSITION AND TIME		DISTANCE STATUTE MILES SHOR	RAN	SUM
34	0908	26.945	14.418	41.363
35	0909	26.741	14.627	41.368
36	0910	26.522	14.846	41.368
37	0911	26.302	15.055	41.357
38	0912	26.084	15.276	41.360
39	0913	25.868	15.493	41.361
40	0914	25.652	15.710	41.362
41	0915	25.442	15.923	41.367
42	0916	25.232	16.137	41.369
43	0917	25.007	16.355	41.362
44	0918	24.792	16.573	41.365
45	0919	24.575	16.789	41.364
46	0920	24.365	17.002	41.367
47	0921	24.149	17.217	41.366
48	0922	23.935	17.432	41.367
49	0923	23.718	17.650	41.368
50	0924	23.5o5	17.865	41.370
51	0925	23.285	18.079	41.364
52	0926	23.054	18.306	41.360
53	0927	22.844	18.527	41.371
54	0928	22.629	18.739	41.367
55	0929	22.421	18.934	41.355
56	0930	22.205	19.156	41.361
57	0931	21.990	19.371	41.361
58	0932	21.780	19.586	41.366
59	0933	21.555	19.806	41.361
60	0934	21.341	20.020	41.361
61	0935	21.120	20.243	41.363
62	0936	20.905	20.462	41.367

POSITION AND TIME		DISTANCE STATUTE MILES SHOR	RAN	SUM
63	0937	20.685	20.690	41.375
64	0938	20.455	20.912	41.367
65	0939	20.242	21.124	41.366
66	0940	20.018	21.344	41.362
67	0941	19.805	21.560	41.365
68	0942	19.583	21.783	41.366
69	0943	19.364	21.695	41.359
70	0944	19.147	22.215	41.362
71	0945	18.925	22.440	41.365
72	0946	18.708	22.660	41.364
73	0947	18.486	22.879	41.365
74	0948	18.267	23.091	41.358
75	0949	18.047	23.317	41.364
76	0950	17.835	23.532	41.367
77	0951	17,615	23.752	41.367
78	0952	17.387	23.979	41.366
79	0953	17.177	24.189	41.366
80	0954	16.958	24.405	41.363
81	0955	16.755	24.610	41.365
82	0956	16.532	24.835	41.367
83	0957	16.320	25.041	41.361
84	0958	16.102	25.259	41.361
85	0959	15.891	25.472	41.363
86	1000	15.675	25.694	41.369
87	1001	15.463	25.902	41.365
88	1002	15.251	26.111	41.362
89	1003	15.035	26.328	41.363
90	1004	14.821	26.546	41.367
91	1005	14.606	26.761	41.367

TABLE I (Continued)

POSITION AND TIME		DISTANCE STATUTE MILES SHOR	RAN	SUM	POSITION AND TIME		DISTANCE STATUTE MILES SHOR	RAN	SUM	POSITION AND TIME		DISTANCE STATUTE MILES SHOR	RAN	SUM
92	1006	14.386	26.976	41.362	123	1040	20.811	21.552	41.363	153	1111	27.377	13.987	41.364
93	1007	14.151	27.212	41.363	124	1043	20.538	20.822	41.360	154	1112	27.617	13.748	41.365
94	1008	13.952	27.411	41.363	125	1044	20.779	20.581	41.360	155	1113	27.857	13.511	41.368
95	1009	13.749	27.619	41.366	126	1045	21.015	20.346	41.361	156	1114	28.080	13.282	41.362
96	1010	13.541	27.836	41.376	127	1046	21.659	20.098	41.357	157	1115	28.317	13.041	41.358
97	1011	13.321	28.044	41.365	128	1047	21.507	19.856	41.363	158	1116	28.563	12.801	41.364
98	1015	13.695	27.672	41.367	130	1048	21.759	19.613	41.372	159	1117	28.800	12.563	41.363
99	1016	13.937	27.426	41.363	131	1049	21.987	19.371	41.358	160	1118	29.026	12.331	41.357
100	1017	14.195	27.170	41.365	132	1050	22.225	19.132	41.357	161	1119	29.264	12.093	41.357
101	1018	14.445	26.920	41.365	133	1051	22.477	18.886	41.363	162	1120	29.506	11.858	41.364
102	1019	14.686	26.676	41.362	134	1052	22.717	18.646	41.363	163	1121	29.891	11.475	41.364
103	1020	14.933	26.427	41.360	135	1053	22.962	18.398	41.360	164	1122	29.996	11.369	41.365
104	1021	15.183	26.176	41.359	136	1054	23.202	18.161	41.363	165	1123	30.226	11.138	41.364
105	1022	15.432	25.933	41.365	137	1055	23.452	17.914	41.364	166	1124	30.466	10.908	41.374
106	1023	15.675	25.689	41.364	138	1056	23.697	17.665	41.362	167	1125	30.698	10.666	41.364
107	1024	15.922	25.441	41.363	139	1057	23.927	17.434	41.361	168	1126	30.944	10.420	41.364
108	1025	16.167	25.196	41.363	140	1058	24.242	17.120	41.362	169	1127	31.182	10.181	41.363
109	1026	16.410	24.949	41.359	141	1059	24.422	16.945	41.365	170	1128	31.431	09.934	41.365
110	1027	16.658	24.706	41.364	142	1100	24.658	16.702	41.360	171	1129	31.681	09.681	41.362
111	1028	16.903	24.460	41.363	143	1101	24.916	16.446	41.362	172	1130	31.916	09.444	41.362
112	1029	17.137	24.225	41.362	144	1102	25.157	16.202	41.359	173	1131	32.163	09.199	41.362
113	1030	17.386	23.976	41.362	145	1103	25.409	15.955	41.364	174	1132	32.396	08.967	41.363
114	1031	17.634	23.731	41.365	146	1104	25.642	15.722	41.364	175	1133	32.651	08.719	41.370
115	1032	17.898	23.461	41.359	147	1105	25.893	15.467	41.360	176	1134	32.866	08.497	41.363
116	1033	18.115	23.246	41.361	148	1106	26.142	15.222	41.364	177	1135	33.119	08.243	41.362
117	1034	18.355	23.002	41.357	149	1107	26.380	14.987	41.367	178	1136	33.370	07.994	41.364
118	1035	18.614	22.749	41.363	150	1108	26.632	14.732	41.364	179	1137	33.616	07.749	41.365
119	1036	18.840	22.723	41.363	151	1109	26.876	14.487	41.363	180	1138	33.835	07.531	41.366
120	1037				152	1110	27.122	14.243	41.365	181	1139	34.063	07.292	41.355

TABLE I (Concluded)

POSITION AND TIME		DISTANCE STATUTE MILES SHOR	RAN	SUM
182	1140	34.300	07.061	41.361
183	1141	34.525	06.840	41.365
184	1142	34.768	06.594	41.362
185	1143	34.982	06.378	41.360

MEAN OF 177 OBSERVATIONS . . .

IN STATUTE MILES 41.364

Fixes by sextant were taken at intervals of about five minutes simultaneously with the SHORAN fix. The scaled values were taken and compared with the appropriate SHORAN distance to make a computation of the station 'error' or correction factor. See TABLE II.

TABLE I-A COMPUTATION OF STATION ERROR FROM TABLE I DATA.
ZERO SET 99.806 29 September 1945

POSITION and STATION	SHORAN DISTANCES Statute Miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCE SHOR (5-4)	RAN
9 SHOR	33.158	33.158	53363	53328	- 25	
RAN	08.225	08.225	13237	13306		+ 69
11 SHOR	32.647	32.647	52540	52544	- 4	
RAN	08.725	08.725	14042	14088		+ 46
16 SHOR	31.398	31.397	50529	50552	+ 23	
RAN	09.972	09.972	16048	16072		- 24
21 SHOR	30.218	30.217	48630	48624	+ 6	
RAN	11.175	11.175	17984	18000		+ 16
26 SHOR	29.032	291031	46721	46624	(+ 97)	
RAN	12.352	12.352	19879	20000		(+114)
31 SHOR	26.662	26.661	42907	42904	- 3	
RAN	xx					
35 SHOR	25.460	25.459	40972	40958	- 14	
39 SHOR	24.274	24.272	39062	39080	+ 18	
40 SHOR	23.814	23.812	38322	38296	- 26	
41 SHOR	23.695	23.693	38130	38128	- 2	
42 SHOR	23.635	23.633	38034	38032	- 2	

POSITION and STATION	SHORAN DISTANCES Statute Miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCES SHOR (5-4)	RAN
43 SHOR	23.615	23.613	38002	38000	- 2	
44 SHOR	23.398	23.396	37652	37784	(-132)	
45 SHOR	23.398	23.395	37651	37664	+ 13	
46 SHOR	23.450	23.447	37739	37736	- 3	
47 SHOR	23.538	23.535	37881	37824	+ 57	
						+ 11
50 SHOR	25.448	25.445	40950	40976	+ 26	
54 SHOR	26.605	26.602	42812	42834	+ 22	
RAN	14.776	14.777	23781	23792		+ 11
59 SHOR	27.790	27.786	44717	44744	+ 27	
RAN	13.600	13.601	21889	21880		- 9
64 SHOR	28.950	28.946	46584	46568	- 16	
RAN	12.427	12.428	20001	20064		+ 63
69 SHOR	30.120	30.116	48467	48480	+ 13	
RAN	11.259	11.260	18121	18144		+ 23
74 SHOR	31.287	31.283	50345	50452	+ 11	
RAN	10.085	10.087	16234	16272		+ 38

TABLE I-A (concluded)

POSITION and STATION	SHORAN DISTANCES Statute Miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCE SHOR (5-4)	RAN
79 SHOR	32.445	32.441	52209	52224	+ 15	
RAN	08.930	08.932	14375	14400		+ 25
84 SHOR	33.570	33.566	54032	54032	0	
RAN	07.808	07.810	12569	12592		+ 23
89 SHOR	34.635	34.630	55732	55744	+ 12	
RAN	06.739	06.741	10848	10888		+ 40
91 SHOR	35.060	35.055	56432	56480	+ 48	
RAN	06.316	06.318	10168	10160		- 8
MEAN DIFFERENCES IN METERS					+ 3.1	+ 22.2
MEAN DIFFERENCES IN STATUTE MILES					+ 0.002	+ 0.014

TABLE II COMPUTATION OF SHORAN CORRECTION FACTORS
Line (b) 30 September 19 45

POSITION and STATION	SHORAN DISTANCES Statute Miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCE SHOR (5 - 4)	RAN
3 SHOR	34.767	34.764	55947	56222	(+275)	
RAN	06.591	06.604	10628	10354		(-273)
12 SHOR	31.640	31.641	50921	51102	(+181)	
RAN	09.714	09.724	15649	15482		(-167)
17 SHOR	30.580	30.581	49216	49998	- 18	
RAN	10.778	10.788	17361	17410		+ 49
22 SHOR	29.500	29.501	47477	47455	- 22	
RAN	11.857	11.867	19098	19145		+ 45
27 SHOR	28.434	28.435	45762	45719	- 43	
RAN	12.923	19.933	20814	20881		+ 67
32 SHOR	27.378	27.378	44061	44064	+ 3	
RAN	13.978	13.988	22512	22536		+ 24
37 SHOR	26.302	26.302	42329	42336	+ 7	
RAN	15.045	15.055	24229	24264		+ 35
42 SHOR	25.232	25.232	40607	40609	+ 2	
RAN	16.127	16.137	25970	25991		+ 21
47 SHOR	24.149	24.149	38864	38865	+ 1	
RAN	17.207	17.217	27708	27735		+ 27
52 SHOR	23.054	23.054	37102	37098	- 4	
RAN	18.297	18.306	29461	29502		+ 41

POSITION and STATION	SHORAN DISTANCES Statute Miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCE SHOR (5 - 4)	RAN
57 SHOR	21.990	21.990	35390	35379	- 11	
RAN	19.362	19.371	31175	31221		+ 44
62 SHOR	20.905	20.905	33643	33620	- 23	
RAN	20.454	20.462	32931	32980		+ 49
67 SHOR	19.805	19.805	31873	31829	- 44	
RAN	21.552	21.560	34698	34771		+ 73
72 SHOR	18.703	18.704	30101	30102	- 1	
RAN	22.653	22.660	36468	36498		+ 30
77 SHOR	17.614	17.615	28349	28383	(++34)	
RAN	23.745	23.752	38225	38217		- 8
82 SHOR	16.531	16.532	26606	26648	+ 42	- 16
RAN	24.828	24.835	39968	39952		- 16
87 SHOR	15.462	15.463	24883	24944	+ 61	
RAN	25.896	25.902	41685	41656		- 29
92 SHOR	14.385	14.386	23152			
RAN	26.970	26.976	43414			
97 SHOR	13.320	13.321	21438			
RAN	28.038	28.044	45133			
98 SHOR	13.695	13,696	22042			
RAN	27.666	27.672	44534			

TABLE II (Concluded)

POSITION and STATION	SHORAN DISTANCES Statute Miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCE SHOR (5-4)	RAN
103 SHOR	14.933	14.933	24032			
RAN	26.421	26.427	42530			
108 SHOR	16.167	16.167	26018	25976	- 42	
RAN	25.190	25.196	40549	40624		+ 75
113 SHOR	17.387	17.386	27980	27991	+ 11	
RAN	23.970	23.973	38581	38609		+ 28
118 SHOR	18.615	18.614	29956	29950	- 6	
RAN	22.743	22.749	36611	36650		+ 39
123 SHOR	19.813	19.811	31882	31917	+ 35	
RAN	21.546	21.552	34685	34683		- 2
126 SHOR	21.018	21.015	33820	33844	+ 22	
RAN	20.340	20.346	32744	32756		+ 14
132 SHOR	22.228	22.225	35768	35803	+ 35	
RAN	19.126	19.132	20790	30797		+ 7
137 SHOR	23.455	23.452	37742	37707	- 35	
RAN	17.908	17.916	28833	28893		+ 60
142 SHOR	24.661	24.658	39683	39714	+ 31	
RAN	16.695	16.702	26879	26886		+ 7
143 SHOR	25.896	25.893	41671	41673	- 2	
RAN	15.460	15.467	24892	24927		+ 35
152 SHOR	27.125	27.122	43649	43656	+ 7	
RAN	14.235	14.243	22922	22944		+ 22
157 SHOR	28.320	28.317	45572	45624	+ 52	
RAN	13.033	13.041	20988	20976		- 12
162 SHOR	29.510	29.506	47485	47519	+ 34	
RAN	11.850	11.858	19084	19081		- 3
167 SHOR	30.702	30.698	49404	49407	- 4	
RAN	10.658	10.666	17165	17209		+ 44
172 SHOR	31.920	31.916	51364	51334	- 30	
RAN	09.435	09.443	15197	15266		+ 69
177 SHOR	33.123	33.119	53300	53669	(+369)	
RAN	08.234	08.243	13266	12931		(-335)
182 SHOR	34.304	34.300	55201	55188	- 13	
RAN	07.051	07.061	11363	11412		+ 39
185 SHOR	34.986	34.982	56298	56332	+ 34	
RAN	06.368	06.378	10264	10268		+ 4
MEAN DIFFERENCES IN METERS					+ 3.6	+ 28.3
MEAN DIFFERENCES IN STATUTE MILES					+ 0.002	+ 0.016

TABLE III COMPUTATION OF STATION CORRECTION FACTORS
LINE A 1 OCTOBER 1945

POSITION and STATION	SHORAN DISTANCES Statute Miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCE (5 - 4) SHOR	RAN
1 SHOR	40.754	40.752	65584	65502	- 82	
RAN	05.525	05.532	8903	8933		+ 30
6 SHOR	41.715	41.713	67131	67005	(-126)	
RAN	08.852	08.859	14257	14267		(+ 10)
9 SHOR	42.427	42.425	68277	68165	(-112)	
RAN	10.898	10.904	17548	17562		(+ 14)
12 SHOR						
RAN	12.928	12.934	20815	20844		+ 29
15 SHOR	42.962	42.959	69136	69124	(- 12)	
RAN	14.985	14.991	24126	23831		(+195)
18 SHOR	43.252	43.249	69603	69476	(+127)	
RAN	16.588	16.594	26706	26581		(-125)
21 SHOR	41.175	41.172	66260	66206	- 54	
RAN	16.607	16.613	26736	26723		- 13
22 SHOR	39.096	39.093	62914	92919	+ 5	
RAN	16.957	16.962	27298	27269		- 29
27 SHOR	37.045	37.042	59613	59600	- 13	
RAN	17.618	17.623	28362	28365		+ 3
30 SHOR	35.020	35.017	56355	56213	(-132)	
RAN	18.416	18.421	29646	29869		(+223)

POSITION and STATION	SHORAN DISTANCES Statute Miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCE (5 - 4) SHOR	RAN
33 SHOR	33.047	33.044	53179	53099	- 80	
RAN	19.357	19.362	31160	31228		+ 68
36 SHOR	31.114	31.111	50068	50036	- 32	
RAN	20.540	20.545	33064	33043		- 21
39 SHOR	29.172	29.168	46942	46973	+ 31	
RAN	21.861	21.865	35188	35154		- 34
42 SHOR	27.194	27.190	43758	43718	- 40	
RAN	23.248	23.252	37420	37418		+ 2
45 SHOR	25.232	25.228	40601	40656	+ 55	
RAN***						
48 SHOR	23.363	23.359	37593	37705	(+112)	
51 SHOR	21.545	21.541	34667	34697	+ 30	
54 SHOR	21.839	21.835	35140	35146	+ 6	
55 SHOR	22.059	22.055	35494	35506	:+ 12	
56 SHOR	22.324	22.320	35721	35922	+ 2	
57 SHOR	22.599	22.595	36363	36386	+ 25	
58 SHOR	22.896	22.892	36841	36865	+ 24	

TABLE III (Concluded)

POSITION and STATION	SHORAN DISTANCES Statute Miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCE SHOR RAN (5 - 4)
59 SHOR	23.206	23.202	37340	37377	+ 37
60 SHOR	23.532	23.528	37865	37913	+ 48
61 SHOR	23.880	23.876	38425	38441	+ 16
62 SHOR	24.232	24.227	38990	39017	+ 27
63 SHOR	24.601	24.596	39584	39585	+ 1
64 SHOR	24.983	24.978	40198	40226	+ 28
65 SHOR	25.384	25.379	40844	40888	+ 44
66 SHOR	25.786	25.781	41491	41520	+ 29
67 SHOR	26.188	26.183	42138	42184	+ 46
68 SHOR	26.615	26.610	42825	42856	+ 31
69 SHOR	27.055	27.050	43533	43575	+ 42
70 SHOR	27.525	27.520	44289	44311	+ 22

POSITION and STATION	SHORAN DISTANCES Statute Miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCE SHOR RAN (5 - 4)
71 SHOR	28.480	28.475	45826	45830	+ 4
72 SHOR	28.962	28.957	46602	46637	+ 35

	SHOR	RAN
MEAN DIFFERENCES IN METERS	+ 10.3	+ 3.4
MEAN DIFFERENCES IN STATUTE MILES	+0.006	+0.002

*** Only Major Casualty occured this day. The receiver unit in the MONITOR at Station RAN burned out due to a shorted capacitor in one of the I.F. coupling transformers.

TABLE IV COMPUTATION OF STATION CORRECTION FACTOR
Line B 2 October 1945

POSITION and STATION	SHORAN DISTANCES Statute miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCE SHOR (5 - 4)	RAN	POSITION AND STATION	SHORAN DISTANCES Statute Miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCE SHOR (5 - 4)	RAN
1 SHOR	40.292	40.292	64844	64776	- 68		31 SHOR	33.908	33.906	54567	54064	(-507)	
RAN	04.694	04.704	7570	7584		+ 14	RAN	17.808	17.808	28659	28928		(+269)
5 SHOR	40.904	40.904	65829	65792	- 37		37 SHOR	29.815	29.813	47980	47976	- 4	
RAN	07.382	07.392	11896	11984		+ 88	RAN	20.259	20.258	32602	32608		+ 6
8 SHOR	41.716	41.716	67136	67088	- 48		40 SHOR	27.796	27.794	44730	44760	+ 30	
RAN	09.633	09.642	15517	15576		+ 59	RAN	21.595	21.595	34754	34736		- 18
9 SHOR	41.480	41.480	66756	66768	+ 12		43 SHOR	25.790	25.788	41502	41512	+ 10	
RAN	09.794	09.803	15776	15752		- 24	RAN	23.088	23.088	37157	37168		+ 11
11 SHOR	40.544	40.544	65249	65112	(-137)*		46 SHOR	23.845	23.844	38373	38360	- 13	
RAN	10.095	10.104	16261	16248		*(- 13)	RAN	24.728	24.728	39796	39792		- 4
14 SHOR	41.386	41.386	66606	66504	(-102)		49 SHOR	21.916	21.915	35269	35304	+ 35	
RAN	12.151	12.159	19568	19584		(+ 16)	RAN	26.445	26.445	42559	42520		- 39
17 SHOR	42.235	42.235	67970	67952	- 18		52 SHOR	20.055	20.054	32258	32296	+ 38	
RAN	14.214	14.221	22887	22904		+ 17	RAN	28.224	28.225	45424	45416		- 8
22 SHOR	40.105	40.104	64541	64544	+ 3		55 SHOR	18.240	18.239	29353	29384	+ 31	
RAN	15.430	15.434	24839	24816		- 23	RAN	30.052	30.053	48366	48312		- 54
25 SHOR	38.062	38.061	61253	61272	+ 19		58 SHOR	16.484	16.483	26527	26544	+ 17	
RAN	15.918	15.921	25622	25608		- 14	RAN	31.912	31.913	51359	51296		- 63
28 SHOR	35.985	35.984	57911	57880	- 31		61 SHOR	14.824	14.822	23854	23904	+ 50	
RAN	16.742	16.743	26945	26904		- 41	RAN	33.773	33.774	54354	54336		- 18

TABLE IV (Continued)

POSITION and STATION	SHORAN DISTANCES Statute Miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCE SHOR (5 - 4)	RAN
64 SHOR	13.330	13.328	21449	21504	+ 55	
RAN	35.648	35.649	57372	57384		+ 12
67 SHOR	12.041	12.038	19373	19480	(+107)	
RAN	37.582	37.582	60483	60464		(- 9)
70 SHOR	11.102	11.099	17862	17472	(+390)	
RAN	39.544	39.544	63640	63864		(+224)
73 SHOR	10.243	10.240	16480	16584	(+104)	
RAN	41.499	41.499	66786	66976		(+190)
75 SHOR	08.899	08.896	14317	13896	(-421)	
RAN						
78 SHOR	09.477	09.474	15247	15112	(-135)	
RAN	39.737	39.738	63952	64088		(+136)
81 SHOR	10.582	10.579	17025	17112	+ 87	
RAN	37.807	37.807	60845	60800		- 45
84 SHOR	11.934	11.931	19201	19272	+ 71	
RAN	35.908	35.910	57792	57720		- 72
87 SHOR	13.437	13.434	21620	21672	+ 50	
RAN	34.015	34.017	54745	54760		+ 15
90 SHOR	15.095	15.092	24288	24336	+ 48	
RAN	32.102	32.105	51668	51720		+ 52

POSITION and STATION	SHORAN DISTANCES Statute Miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCE SHOR (5 - 4)	RAN
93 SHOR	16.837	16.834	27092	27168	+ 76	
RAN	30.263	30.267	48710	48712		+ 2
96 SHOR	18.637	18.634	29989	30072	+ 83	
RAN	28.478	28.482	45838	45832		- 6
100 SHOR	21.096	21.093	33946	34064	(+118)	
RAN	26.137	26.142	42072	42072		0
103 SHOR	23.000	22.997	37010	36992	+ 18	
RAN	24.405	24.411	39286	39352		+ 66
106 SHOR	24.907	24.904	40079	40136	+ 57	
RAN	22.768	22.774	36651	36648		- 3
109 SHOR	26.887	26.884	43266	43288	+ 22	
RAN	21.149	21.156	34047	34032		- 15
113 SHOR	29.886	29.883	48092	48128	+ 36	
RAN	19.018	19.025	30618	30600		- 18
117 SHOR	32.541	32.538	52365	52376	+ 11	
RAN	17.252	17.259	27776	27808		+ 32
123 SHOR	36.384	36.381	58550	58592	+ 42	
RAN	15.321	15.328	24668	24744		+ 76
126 SHOR	38.360	38.356	61728	61688	- 40	
RAN	14.629	14.636	23554	23640		+ 86

TABLE IV (Continued)

POSITION and STATION	SHORAN DISTANCES Statute Miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCE (5 - 4) SHOR	RAN
129 SHOR	40.427	40.423	65055	65112	+ 57	
RAN	14.274	14.281	22983	22992		+ 9
132 SHOR	42.465	42.461	48334	68288	- 46	
RAN	14.164	14.170	22804	22856		+ 52
135 SHOR	44.520	44.516	71642	71608	- 34	
RAN	14.396	14.402	23178	23200		+ 22
137 SHOR	45.924	45.920	73901	73976	+ 76	
RAN	14.759	14.765	23762	23784		+ 22
139 SHOR	47.335	47.331	76172	76224	+ 52	
RAN	15.177	15.183	24435	24472		+ 37
140 SHOR	47.180	47.176	75923	75888	- 35	
RAN	14.923	14.929	24026	24040		+ 14
142 SHOR	45.740	45.737	73607	73672	+ 65	
RAN	14.484	14.489	23318	23360		+ 42
144 SHOR	44.096	44.093	70961	70968	+ 7	
RAN	14.150	14.155	22780	22776		- 4
145 SHOR						
RAN	13.806	13.811	22227	22264		+ 37
148 SHOR						
RAN	11.678	11.683	18802	18816		+ 14
151 SHOR						
RAN	09.678	09.682	15582	15696		(+114)
154 SHOR	40.360	40.357	64949	64904	- 55	
RAN	07.995	07.999	12873	12856		- 17

MEAN DIFFERENCE IN METERS . . . . + 17 - 1.4

MEAN DIFFERENCE IN STATUTE MILES . . . . +0.011 -0.001

TABLE V COMPUTATION OF STATION CORRECTION FACTORS
Line C 3 October 1945

POSITION and STATION	SHORAN DISTANCES Statute Miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCE SHOR (5 - 4)	RAN	POSITION and STATION	SHORAN DISTANCES Statute Miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCE SHOR (5 - 4)	RAN
1 SHOR	41.123	41.124	66183	66184	+ 1		35 SHOR	35.625	35.619	57323	57432	(-109)	
RAN	05.322	05.322	8565	8600		+ 35	RAN	17.637	17.637	28384	28352		(- 32)
4 SHOR	41.709	41.708	67123	67128	+ 5		38 SHOR	37.632	37.626	60553	60552	- 1	
RAN	07.435	07.435	11966	12000		+ 34	RAN	16.775	16.775	26997	27016		+ 19
8 SHOR	42.427	42.425	68277	68184	- 93		41 SHOR	39.747	39.742	63959	64000	+ 41	
RAN	09.946	09.947	16008	16024		+ 16	RAN	16.254	16.254	26158	26176		+ 18
11 SHOR	40.932	40.929	65869	65920	+ 51		44 SHOR	41.914	41.909	67446	67456	+ 10	
RAN	10.074	10.076	16216	16232		+ 16	RAN	16.067	16.067	25857	25832		- 25
14 SHOR	41.427	41.423	66664	66656	(- 10)		47 SHOR	42.000	41.995	67585	67560	- 25	
RAN	11.781	11.782	18961	19080		(+119)	RAN	15.845	15.846	25502	25488		- 14
17 SHOR	42.321	42.317	68103	68192	+ 89		50 SHOR	39.933	39.930	64293	64312	+ 19	
RAN	13.842	13.843	22278	22264		- 14	RAN	16.004	16.005	25758	25752		- 6
23 SHOR	41.810	41.805	67279	66232	- 47		53 SHOR	37.918	37.913	61015	61016	+ 1	
RAN	16.365	16.365	26337	26360		+ 23	RAN	16.502	16.503	26559	26568		+ 9
26 SHOR	39.762	39.756	63981	83952	- 29		56 SHOR	35.827	35.822	57650	57632	- 18	
RAN	16.566	16.565	26659	26672		+ 13	RAN	17.263	17.264	27784	27776		- 8
29 SHOR	37.700	37.694	60663	60672	+ 9		59 SHOR	35.611	35.606	57303	57328	+ 25	
RAN	17.043	17.042	27427	27432		+ 5	RAN	17.122	17.123	27557	27520		- 37
32 SHOR	35.630	35.624	57331	57984	(+453)		62 SHOR	37.641	37.635	60568	60608	+ 40	
RAN	17.847	17.846	28720	28568		(-162)	RAN	16.318	16.319	26263	26272		+ 9

TABLE V (Continued)

POSITION	SHORAN DISTANCES			SCALED	DIFFERENCE		POSITION	SHORAN DISTANCES			SCALED	DIFFERENCE	
and	Statute	Miles	Meters	Meters	SHOR	RAN	and	Statute	Miles	Meters	Meters	SHOR	RAN
STATION	READ	COR'D	(4)	(5)	(5 -4)		STATION	READ	COR'D	(4)	(5)	(5- 4)	
65 SHOR	39.762	39.756	63981	64024	+ 43		95 SHOR	42.430	42.427	68280	68288	+ 8	
RAN	15.790	15.791	25413	25392		- 21	RAN	14.734	14.735	23714	23776		+ 62
68 SHOR	41.927	41.921	67466	67432	- 34		98 SHOR	41.224	41.221	66339	66312	- 27	
RAN	15.586	15.587	25085	25032		- 53	RAN	14.534	14.537	23395	23472		+ 77
71 SHOR	41.868	41.862	67371	67320	- 51		101 SHOR	39.124	39.122	62961	62904	- 57	
RAN	14.963	14.964	24082	24056		- 26	RAN	14.898	14.902	23982	24024		+ 42
74 SHOR	39.836	39.831	64102	64056	(- 46)		104 SHOR	37.015	37.013	59567	59568	+ 1	
RAN	15.255	15.256	24552	24656		(+104)	RAN	15.570	15.574	25064	25144		+ 80
77 SHOR	37.780	37.775	60793	60704	- 89		107 SHOR	34.855	34.853	56091	56056	- 35	
RAN	15.750	15.751	25349	25392		+ 43	RAN	16.506	16.511	26572	26664		+ 92
81 SHOR	35.828	35.824	57010	56984	- 26		110 SHOR	34.816	34.814	56028	56016	- 12	
RAN	16.727	16.728	26921	26992		+ 71	RAN	16.277	16.283	26205	26240		+ 35
83 SHOR	34.539	34.535	55579	55452	(-127)		113 SHOR	36.862	36.861	59322	59304	- 18	
RAN	16.896	16.897	27193	27272		(+ 78)	RAN	15.375	15.382	24755	24768		+ 13
86 SHOR	36.416	36.412	58600	58656	+ 56		116 SHOR	38.965	38.964	62707	62696	- 11	
	16.004	16.005	25758	25816		+ 58	RAN	14.694	14.700	23657	23696		+ 39
89 SHOR	38.496	38.493	61949	91904	- 45		119 SHOR	41.118	41.117	66172	66144	- 28	
Ran	15.297	15.298	24620	24704		+ 84	RAN	14.382	14.390	23159	23176		+ 16
92 SHOR	40.641	40.638	65401	65360	- 41		122 SHOR	42.003	42.001	67594	67600	+ 6	
RAN	14.867	14.868	23928	23960		+ 32	RAN	13.916	13.923	22407	22440		+ 33

TABLE V (Concluded)

POSITION and STATION	SHORAN DISTANCES Statute Miles READ	COR'D	Meters (4)	SCALED Meters (5)	DIFFERENCE (5 - 4) SHOR	RAN
125 SHOR	40.120	40.118	64564	64536	- 28	
RAN	14.054	14.060	22627	22688		+ 61
128 SHOR	37.978	37.975	61115	61072	- 43	
RAN	14.524	14.530	23384	23448		+ 64
131 SHOR	35.809	35.808	57628	57600	- 28	
RAN	15.314	15.319	24654	24736		+ 82
134 SHOR	34.307	34.303	55206	55216	+ 10	
RAN	15.823	15.827	25471	25480		+ 9
137 SHOR	36.094	36.089	58080	58088	+ 8	
RAN	14.941	14.944	24050	24144		+ 94
140 SHOR	38.178	38.172	61432	61480	+ 48	
RAN	14.193	14.195	22835	22856		+ 21
143 SHOR	40.308	40.302	64860	64888	+ 28	
RAN	13.792	13.794	22199	22224		+ 25
146 SHOR	41.765	41.760	67206	67576	(+370)	
RAN	13.455	13.458	21659	21640		(- 19)
149 SHOR						
RAN	13.636	13.639	21950	21992		+ 42
152 SHOR	37.665	37.661	60610	60608	- 2	
RAN	14.136	14.140	22756	22824		+ 68
155 SHOR	35.466	35.462	57071	57088	+ 17	
RAN	14.980	14.984	24115	24176		+ 61
158 SHOR	54.217	34.214	55062	55080	+ 18	
RAN	15.370	15.375	24744	24784		+ 40
161 SHOR	36.012	36.009	57951	57944	- 7	
RAN	14.523	14.528	23381	23376		- 5
164 SHOR	38.059	38.057	61247	61272	+ 25	
RAN	13.770	13.776	22170	22120		- 50
167 SHOR	40.168	40.166	64641	64624	- 17	
RAN	13.354	13.360	21501	21480		- 21
170 SHOR	41.783	41.782	67242	67176	- 66	
RAN	13.167	13.174	21202	21160		- 42
173 SHOR	41.878	41.877	67395	67216	(-179)	
RAN	11.345	11.352	18369	18368		(- 99)

MEAN DIFFERENCES IN METERS . . . . = 8   + 24

MEAN DIFFERENCES IN STATUTE MILES . . . . -0.005   +0.017

TABLE VI COMPUTATION OF SHORAN CORRECTION FACTORS

Line (e) 5 October 1945 (EE)

POSITION AND TIME		DISTANCE STATUTE MILES SHOR	RAN	SUM
1	30*	35.321	06.033	41.357
2	0831	35.211	06.143	41.354
3	30*	35.081	06.272	41.353
4	0832	34.972	06.381	41.353
5	30*	34.863	06.500	41.363
6	0833	34.752	06.608	41.360
7	30*	34.629	06.736	41.365
8	0834	34.501	06.858	41.359
9	30	34.400	06.959	41.359
10	0835	34.285	07.071	41.356
11	30	34.166	07.194	41.360
12	0836	34.052	07.307	41.359
13	30	33.938	07.422	41.360
14	0837	33.826	07.537	41.363
15	30	33.709	07.656	41.365
16	0838	33.584	07.777	41.361
17	30	33.467	07.898	41.365
18	0839	33.354	08.009	41.363
19	30	33.236	08.128	41.363
20	0840	33.120	08.244	41.364
21	30	32.974	08.389	41.363
22	0841	32.899	08.476	41.365
23	30	32.774	08.591	41.365
24	0842	32.657	08.709	41.366
25	30	32.545	08.821	41.366
26	0843	32.424	08.935	41.359
27	30	32.316	09.046	41.362
28	0844	32.195	09.161	41.356
29	30	32.076	09.284	41.360
30	0845	31.996	09.393	41.358
31	30	31.859	09.507	41.366
32	0846	31.742	09.624	41.366
33	30	31.625	09.743	41.368
35	0847	31.513	09.855	41.368
36	30	31.273	10.084	41.357
37	0848	31.160	10.203	41.363
38	30	31.045	10.318	41.363
39	0849	30.934	10.433	41.367
40	30	30.824	10.541	41.365
41	0851	30.591	10.779	41.370
42	30	30.467	10.896	41.363
43	0852	30.349	11.014	41.363
44	30	30.226	11.135	41.361
45	0853	30.105	11.258	41.363
46	30	29.990	11.373	41.363
47	0854	29.879	11.488	41.367
48	30	29.766	11.613	41.379
49	0855	29.631	11.738	41.369
50	30	29.519	11.846	41.365
51	0856	29.395	11.966	41.361
52	30	29.270	12.095	41.365
53	0857	29.157	12.203	41.360
54	30	29.042	12.321	41.363
55	0858	28.929	12.435	41.364
56	30	28.804	12.559	41.363
57	0859	28.693	12.670	41.363
58	30	28.573	12.797	41.360
59	0900	28.456	12.904	41.360
60	30	28.345	13.014	41.359
61	0901	28.229	13.134	41.363
62	30	28.111	13.253	41.364
63	0902	27.994	13.367	41.363
64	30	27.887	13.480	41.367
65	0903	27.772	13.597	41.369
66	30	27.694	13.718	41.367
67	0904	27.533	13.837	41.370
68	30	27.503	13.961	41.364
69	0905	27.299	14.062	41.361
70	30	27.179	14.185	41.364
71	0906	27.059	14.305	41.364
72	30	26.939	14.423	41.362
73	0907	26.832	14.534	41.366
74	30	26.713	14.649	41.362
75	0908	26.590	14.773	41.363
76	30	26.476	14.885	41.361
77	0909	26.352	15.003	41.356
78	30	26.242	15.115	41.357
79	0910	26.124	15.235	41.359
80	30	26.004	15.355	41.359
81	0911	25.888	15.473	41.361
82	30	25.773	15.590	41.363
83	0912	25.640	15.722	41.362
84	30	25.532	15.834	41.366
85	0913	25.414	15.948	41.362

TABLE VI (concluded)

POSITION AND TIME		DISTANCE STATUTE MILES SHOR	RAN	SUM
86	30	25.294	16.062	41.356
87	0914	25.173	16.191	41.364
88	30	25.054	16.305	41.359
89	0915	24.940	16.424	41.364
90	30	24.825	16.539	41.364
91	0916	24.703	16.661	41.364
92	30	24.572	16.796	41.368
93	0917	24.453	16.911	41.364
94	30	24.338	16.023	41.361
95	0918	24.220	17.142	41.362
96	30	24.095	17.262	41.357
97	0919	23.973	17.390	41.363
98	30	23.856	17.515	41.371
99	0920	23.745	17.628	41.373
100	30	23.625	17.746	41.371
101	0921	23.502	17.863	41.365
102	30	23.384	17.979	41.363
103	0922	23.258	18.006	41.364
104	30	23.139	18.228	41.367
105	0923	23.012	18.352	41.364
106	30	22.896	18.472	41.368
107	0924	22.779	18.588	41.367
108	30	22.656	18.713	41.369
109	0925	22.523	18.845	41.368
110	30	22.405	18.960	41.365
111	0926	22.282	19.081	41.363
112	30	22.174	19.189	41.363
113	0927	22.050	19.312	41.362

POSITION AND TIME		DISTANCE STATUTE MILES SHOR	RAN	SUM
114	30	21.934	19.428	41.362
115	0928	21.823	19.546	41.369
116	30	21.698	19.666	41.364
117	0929	21.570	19.996	41.366
118	30			
119	0930	21.321	20.042	41.364
120	30	21.203	20.161	41.364
121	0931	21.093	20.269	41.362
122	30	20.968	20.396	41.364
123	0932	20.846	20.522	41.368

* Fixes were taken at 30-second intervals. The (*) indicates that this 30-second time belongs to the preceeding minute indicated.

Due to heavy fog setting in at about the center of the base line, it was necessary to break off this run as no visual control was available. The line turned on the BISECTOR of the base line, and regular Hydrographic Survey was continued from this point.

MEAN OF 122 OBSERVATIONS . . . . .

IN STATUTE MILES . . . 41.363

MEAN OF THE VALUE FROM TABLE I
AND THE VALUE FROM TABLE VI . . . .

IN STATUTE MILES . . . 41.364

TABLE W- WEATHER CONDITIONS DURING PERIOD OF OPERATIONS

29 September 1945

TIME	WIND DIRECTION	WIND FORCE	TEMPERATURE	BAROMETER	WEATHER
0600*	calm		50	30.15	o
0700*	calm		50	30.15	c
0800	w	1	51	30.14	c
0900	calm		50	30.12	c
1000	var	0-1	48	30.13	o
1100	sw	2	49	30.11	o
1200*	s	1	51	30.09	o
1300*	var	0-1	50	30.07	c
1400*	var	0-1	50	30.04	o
1500*	var	0-1	49	30.03	o
1600*	var	0-1	49	30.02	o
1700*	var	1	51	29.99	c
1800*	calm		50	29.97	c

30 September 1945

TIME	WIND DIRECTION	WIND FORCE	TEMPERATURE	BAROMETER	WEATHER
0600*	ese	3	46	29.63	o
0700*	e	5	46	29.62	o
0800	e	5	46	29.60	o
0900	e	6	47	29.54	o
1000	e	7	47	29.51	o
1100	e	7	48	29.50	o
1200	ne	7	48	29.46	o
1300	e	5	48	29.43	om
1400	ene	5	48	29.41	o
1500	ene	6	47	29.39	o
1600	ene	7	47	29.38	o
1700	ne	6-7	47	29.38	o
1800*	ne	5-7	48	29.38	oq

1 October 1945

TIME	WIND DIRECTION	WIND FORCE	TEMPERATURE	BAROMETER	WEATHER
0600*	n	3	45	29.47	c
0700*	n	3	46	29.50	c
0800	n	2	48	29.52	c
0900	n	2	48	29.53	bc
1000	nne	2	50	29.55	bc
1100	nne	2	55	29.55	bc
1200	nne	2	54	29.55	bc
1300	wnw	3	54	29.53	or
1400	calm		47	29.53	or
1500*	var	1	46	29.53	o
1600*	calm		46	29.54	o
1700*	calm		46	29.54	o
1800*	calm		45	29.55	o

2 October 1945

TIME	WIND DIRECTION	WIND FORCE	TEMPERATURE	BAROMETER	WEATHER
0600*	calm		43	29.73	o
0700*	sw	1	42	29.74	cr
0800	sw	1	44	29.75	c
0900	sw	1	45	29.77	c
1000	nw	1	45	29.77	c
1100	nw	3	46	29.78	c
1200	nw	5	50	29.78	c
1300	nw	6-7	45	29.78	crq
1400	nw	5	43	29.80	crq
1500	n	3	43	29.83	crq
1600	nw	4	47	29.83	c
1700*	nw	2	46	29.84	c
1800*	nw	1	45	29.86	c

TABLE W- Weather (Concluded)

Date	TIME	WIND DIRECTION	WIND FORCE	TEMPERATURE	BAROMETER	WEATHER
3 October 1945	0600	calm		44	29.91	c
	0700	nnw	2	45	29.91	cp
	0800	nnw	2	45	29.91	cp
	0900	nnw	2	46	29.91	bc
	1000	n	2	46	29.92	bc
	1100	n	3	46	29.92	bc
	1200	n	2	47	29.92	bc
	1300	n	2	48	29.90	bc
	1400	n	2	48	29.90	bc
	1500	n	2	47	29.89	bc
	1600	n	2	47	29.87	bc
	1700*	ne	1	45	29.86	c
	1800*	calm		44	29.86	c
4 October 1945	0600	sse	5	45	29.58	cr
	0700	sse	5	45	29.56	oc
	0800	sse	5	45	29.53	or
	0900	sse	6	46	29.48	or
	1000	sse	5	46	29.45	or
	1100	se	6	46	29.41	or
	1200	se	6	47	29.41	or
	1300	se	6-7	47	29.35	or
	1400	w.s	6	49	29.34	cm
	1500	w.s	5	50	29.34	cm
	1600	w.s	4	50	29.34	cm
	1700*	w	3	48	29.34	c
	1800*	sw	2	48	29.35	c
5 October 1945	0600	calm		47	29.32	or
	0700	sw	0-1	47	29.31	od
	0800	calm		48	29.31	om
	0900	sw	2-3	48	29.31	om
	1000	sw	5	47	29.27	om
	1100	sw	4-5	47	29.31	om
	1200	sw	6	47	29.29	o
	1300	w	7	47	29.25	o
	1400	w	7	47	29.24	o
	1500	w	7	47	29.22	o
	1600	w	6	47	29.24	om
	1700*	s	1	47	29.23	om
	1800*	calm		46	29.24	c

* Ship protected by anchorage in harbor.