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LESSON TEXT No. 49

MARINE AND AIRCRAFT RADIO BEACON AND DIRECTIONAL FINDERS

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Washington, D. C.

An aim in life is the only fortune worth the finding; and it is not to be found in foreign lands, but in the heart itself.

—*Robert Louis Stevenson.*

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MARINE AND AIRCRAFT RADIO BEACON AND DIRECTIONAL FINDERS

The problem of improving the safety of marine and aerial navigation in time of fog and poor visibility has always been an important one.

During the past few years, the application of strictly radio methods to the art of navigation has been increasing, both in

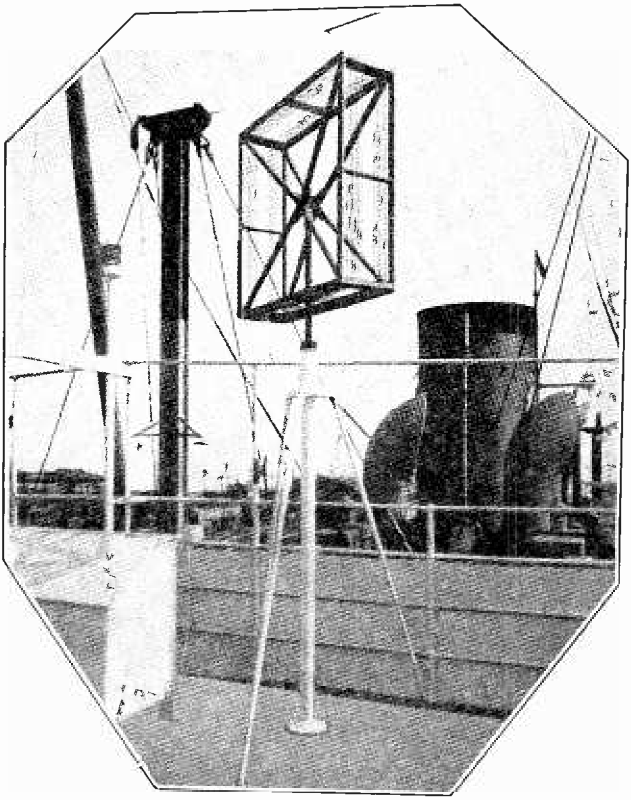

Fig. 1—An Early Type of Radio Compass Loop Installed on Shipboard.

usage and in the actual number of new installations made on shipboard. This is also true to its application in aircraft of all varieties. We shall take up Marine Direction Finders first.

The radio direction finder is becoming an accepted part of modern navigation. Both the active and non-active types are used. Radio-beacons are called "active," while those located on shipboard, taking directions from distant transmitters are "non-active."

The present state of the art of direction finding is due to the tireless work of a number of radio engineers, located in the various countries of Europe, and in America.

The first types of direction finding receivers were combined with special antenna systems consisting of large fixed

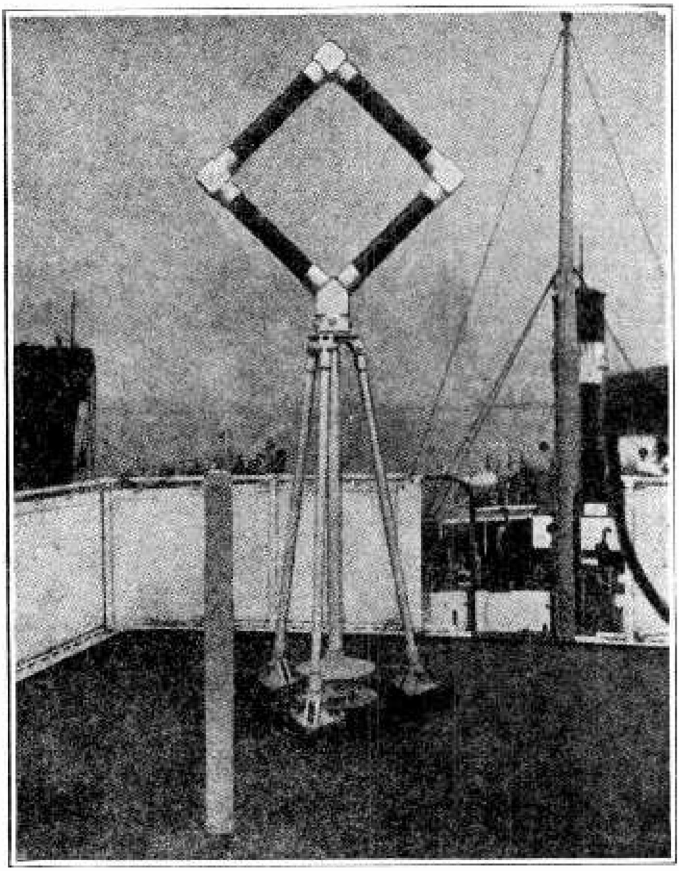

Fig. 2—Typical R. C. A. Radio Compass Loop Installed on Board Ship.

loops and working with an instrument that has been termed a "radio-goniometer." (This device permits determination of the line of travel of waves as received.)

More recent systems have been developed along the line of the shielded rotating loop antenna, with a specially shaped field that readily detects a minimum field strength when rotated against the direction of the incoming radio signals. With this type of apparatus, the operator can, in a few seconds, get accurate bearings on a far distant transmitter. This bearing is usually read in degrees and can be easily compared with some known direction—as determined by the magnetic compass, for instance.

These two systems are both of the ship installation variety, and the use of the latter is increasing aboard American vessels.

Fundamental Principles

It has long been known that an antenna system of a loop or closed coil has directional properties. The fundamental Radio circuit is made up of inductance and capacity. These elements appear in various forms, and in the ideal circuit, as shown in symbol form in Fig. 3, the inductance is entirely

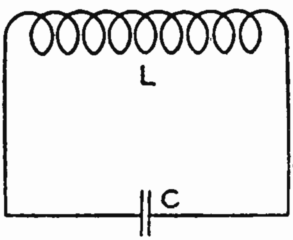

Fig. 3—Simple Closed Coil Circuit Using an Inductance Coil, L, and a Variable Condenser, C.

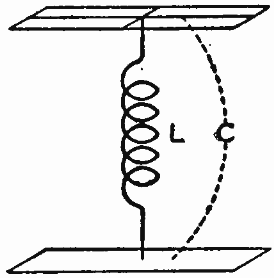

Fig. 4—Antenna (Condenser Type) Consisting of Elevated Conductors, Inductance Coil, L, and Ground or Counterpoise.

concentrated or lumped in the coil L, and the capacity is likewise concentrated or lumped in the condenser C.

Power may be supplied to such a circuit either by applying a resonant voltage across the condenser C, or by inducing a resonant voltage in the coil L, or by action of both in proper phase relation. In the ordinary antenna system, as used in present-day radio communication, we find, generally speaking, that the inductance is substantially concentrated in the form of coil L, and the capacity is formed by a conductor or group of conductors elevated above the ground. The elevated conductor is forming one plate of the condenser while the ground or counterpoise forms the other plate, as shown in Fig. 4.

It may be said, therefore, that energy is received in the ordinary radio antenna system by virtue of the fact that its capacity is exposed to the incoming electromagnetic waves. In other words, energy enters the system by way of its capacity, thereafter to be transferred to its inductance. The electrical capacity of an antenna, as well as the potential impressed upon it by the incoming electromagnetic waves, depends largely upon its physical dimensions. Generally, the size and height of its elevated area is the chief factor, but in special types of antennas, the length of the antenna wires is most important.

In Fig. 5, we have what may be considered as the reverse of the antenna system shown in Fig. 4. In this system, the energy is received by virtue of the fact that its inductance, L, is exposed to the incoming electromagnetic waves. In other words, energy enters the system by way of its inductance, thereafter to be transferred to its capacity.

The inductance of the coil, L, depends upon the number of turns, the area enclosed, and the spacing of the turns of wire.

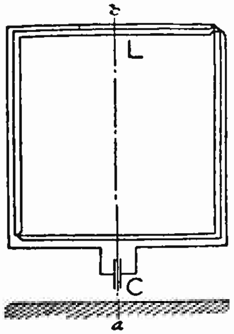

Fig. 5—Antenna (Inductance Type) Consisting of Closed Coil, L, and a Variable Condenser, C.

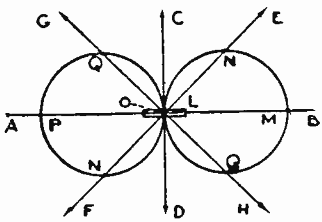

Fig 6.—Theoretical Directional Characteristic of a Closed Coil Antenna (Figure-of-Eight Characteristic).

The current in the receiving circuit depends largely upon these factors, as well as the resistance of the circuit. For given physical dimensions, however, any value of inductance may be obtained by winding the proper number of turns of wire on the coil, L. The electrical dimensions of the coil system are not so dependent upon its physical dimensions as in the ordinary elevated antenna system. As a matter of fact, a coil system of very small dimensions, as compared with an elevated antenna, may be used for the reception of radio signals with a sensitive vacuum tube receiving set.

The chief advantage of using a coil receiving system lies in its directive properties. If the coil, L, in Fig. 5, for example, is rotated about its vertical axis AB, the received signal intensity, from any given source of transmission, will vary approximately in accordance with the diagram shown in Fig. 6.

Maximum signal intensity OP or OM is obtained when the plane of the coil, L, lies in the direction of the source of transmission A or B. If the source of transmission is in the direction of C or D, or exactly normal, or at right angles to the plane

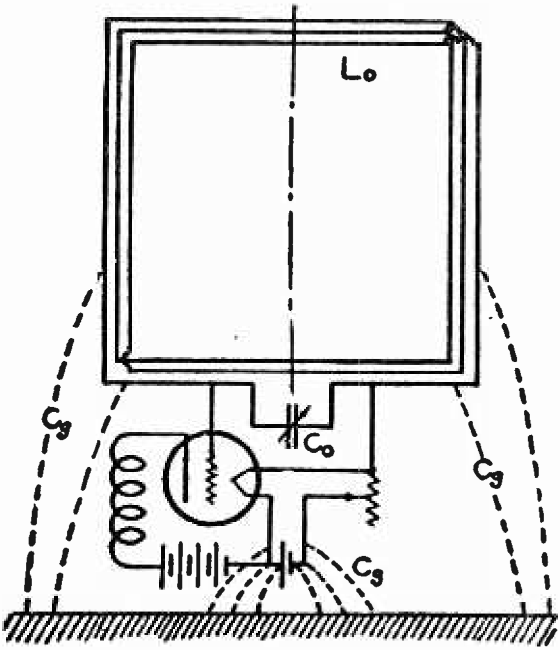

Fig. 7—Coil Antenna Circuit, Showing a Symmetry of Distributed Capacity to Earth.

of the coil L, then the signal intensity is zero. In all other directions, the intensity varies in accordance with the figure-of-eight characteristics in Fig. 6. For example, in directions OE or OF, OG or OH, the distances ON or OQ, respectively,

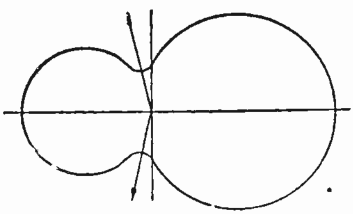

Fig. 8—Characteristic Curve for Coil Type of Antenna Showing the Effects of Both Direct Earth Capacity and the Effect of the Current in the Coil Due to its Capacity Effect to Earth.

represent the relative signal intensities as compared with the maximum OM or OP.

It is immediately apparent, therefore, that if the coil, L, in Fig. 5 is of sufficiently small dimensions to permit rotation about its vertical axis, signals transmitted from any other given source will be received with gradually varying degrees of intensity until the coil becomes normal, or at right angles to the direction in which the transmitting source lies. Then the signal intensity becomes zero. This position of silence is critical and, therefore, may be used to indicate, with great accuracy, the direction of the source of transmission.

It is upon these simple principles that the direction finder, as developed by radio engineers, is based. The theory of its

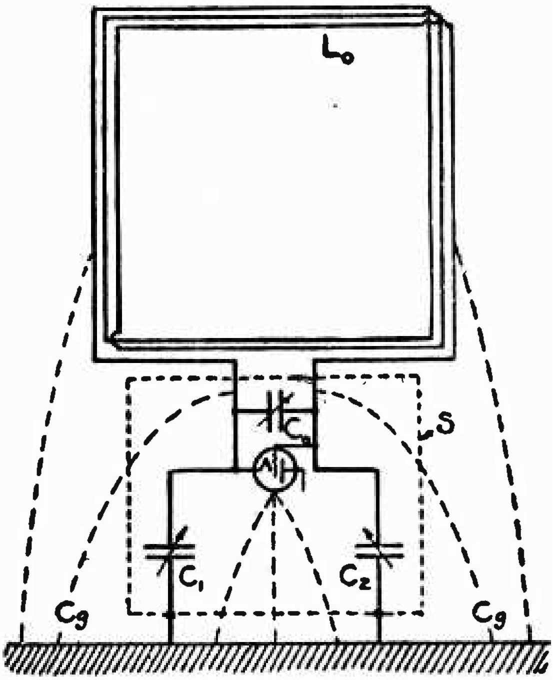

Fig. 9—Diagram Illustrating the Method of Balancing Out the Error Caused by the Capacity Effect to Earth.

design and operation presents a number of interesting problems, however, and it is not until these problems are thoroughly understood that the ideal conditions for accurate direction finding can be realized. In the matter of design, it is important to determine, under given practical conditions, the number of turns of wire and the spacing of the turns which will give maximum received signal intensity for the wavelength or frequency to be received.

Capacity of Loop Circuit to Ground

An important factor which has to be taken into consideration when using a loop antenna in its application as a direction finder is the effect produced in the coil by virtue of the coil structure having an appreciable capacity to earth. Also, the entire coil system, including the detector and amplifier circuit, is electrically unsymmetrical with respect to earth. This results in a distortion of the ideal figure-of-eight "signal intensity" characteristics obtained by rotation of the coil upon its vertical axis. The critical position of "zero signal" intensity no longer exists and the directive qualities of the coil system are distorted.

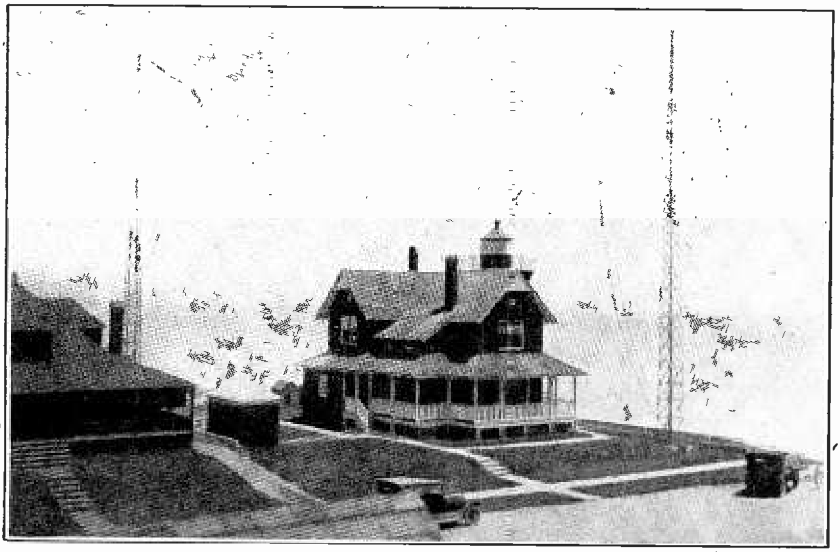

Fig. 10—Radio Fog-Signal Station at Sea Girt, N. J., Lighthouse, Showing Antenna Towers

The Automatic apparatus for sending radio Signals, three dashes at brief intervals, is located in a small room of the building, and is in charge of the one regular lightkeeper at this station.

An examination of Fig. 7 will show that the vacuum tube circuit connected to the variable condenser, Co, will be affected by the potential across the condenser as produced by the current received in the coil Lo, by the direct action upon the coil of the incoming electromagnetic waves. It will also be affected to a lesser extent by the voltage applied to the electron tube due to direct action upon it of the incoming wave through the earth capacities, Cg.

Furthermore, because of the electrically unbalanced relation of the coil system with respect to earth, an appreciable current will be set up in the coil circuit by the incoming wave acting through the earth capacities, Cg. The potential produced by this current across the condenser, Co, will likewise operate upon the vacuum tube.

The ideal figure-of-eight signal intensity characteristic is, therefore, distorted by these additional effects, the degree of distortion depending upon their relative magnitudes. In practice, it often happens that the signal intensity produced by direct action through the earth's capacity is sufficient to destroy the critical zero signal characteristic of the coil when its plane is at right angles to the incoming wave front.

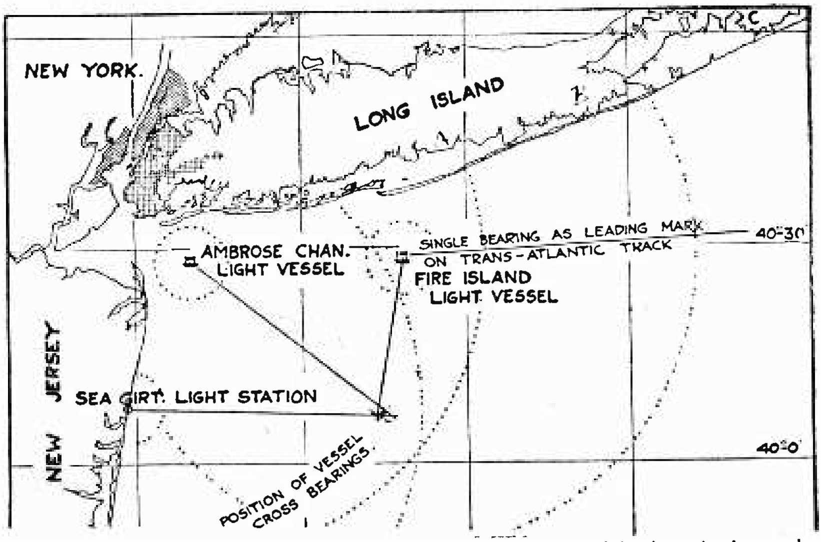

Fig. 11—Sketch Illustrating Radio Beacon Stations Used to Locate Incoming Ships to New York Harbor. Lines Drawn on Chart Indicate Position of Ship.

The complete solution of this problem depends upon obtaining the exact electrical balance of the entire coil system, including the auxiliary vacuum tube apparatus, with respect to earth.

This is accomplished by balancing out this so-called antenna effect by proper adjustment of the variable condensers C1 and C2 connected as shown in Fig. 9. Furthermore, the condensers C0, C1 and C2 together with all auxiliary apparatus should be shielded as shown by the letter S.

In the matter of operation, it is important to obtain, as nearly as possible, the ideal figure-of-eight characteristic with its critical or sharply defined position of "zero signal" intensity.

Also, the operating circuit adjustment and the method of reading bearings must be simple and rapid.

There are two methods of using the direction finding loop. In one case, a number of loops located on shore are used to obtain the position of a ship at sea by simultaneous bearings, see Fig. 11. In the other case, the loop is mounted on the vessel and used to obtain the bearings of the beacon stations on shore. In this case, when the loop is designed for extreme accuracy and provisions are made for determining the unidirectional sense of the signals, it is called a radio compass.

The U. S. Navy Department has established a system of directional finding stations on shore in the vicinity of harbor

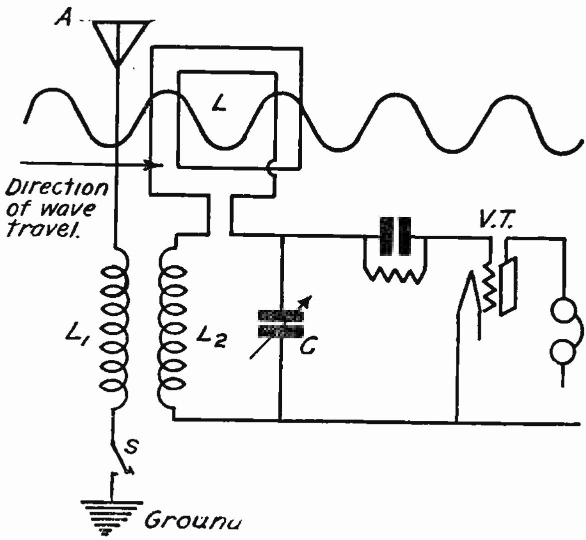

Fig. 12—Circuit Diagram Showing a Loop Antenna in Conjunction with an Elevated Antenna Used for a Direction Finder Having Directional (Unilateral) Characteristics.

entrances or places dangerous to navigation. Each group of receiving stations is connected to a control station which is equipped with a transmitter.

Figure 11 illustrates how three Radio Beacon Transmitting Stations enable ships to determine their bearings or course by the triangulation method.

A vessel desirous of learning its position sends a series of signals to the control beacon station. Each loop station fixes on the vessel and sends the bearing to the control station. If only one loop station is available, only one bearing can be furnished the vessel. Usually, at least three bearings are obtained, thus permitting the latitude and longitude of the vessel to be read direct from a chart. This information is then forwarded by the transmitter to the vessel by radio.

In operation, this system develops several serious faults. If it is used in a very busy harbor, a number of ships may ask for their positions at the same time, and be forced to wait their turn. This is just the reverse of the use of the radio compass aboard ship, for any number of ships can take their positions at the same time, from the same beacon station.

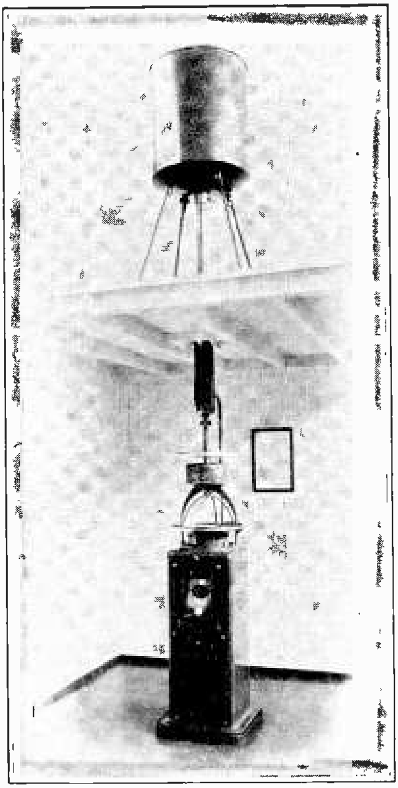

Fig. 13—Kolster Radio Compass Installation on Board Ship.
(Courtesy of Federal Telegraph Co.)

Directional Finders on Board Ship

In the second application of the direction finding loop installed on board ship, the automatic radio beacon stations on shore, or installed on light vessels and lighthouses, send out radio signals similar to light flashes.

Using this method, a bearing is taken from the beacon

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station. The position of the station is determined from a chart, by the characteristic signal it sends. The observation is then made by the captain or master of the vessel and the results are immediately available.

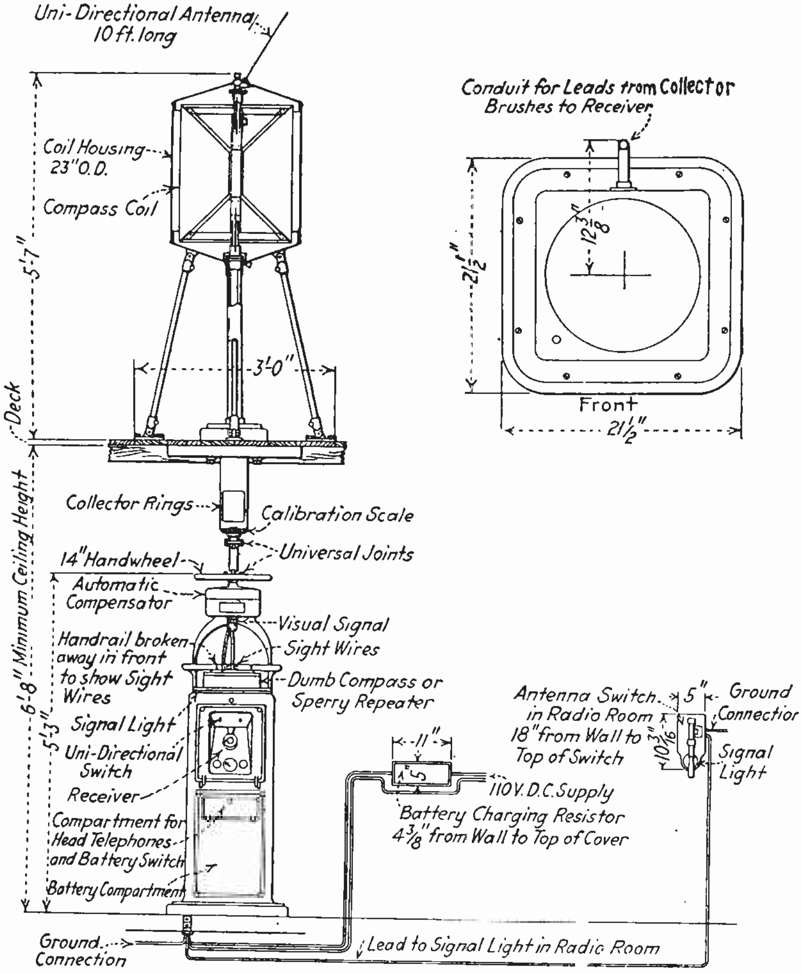

Fig. 14—Drawing Showing Complete Installation of Kolster Radio Compass on Board Ship With the Important Parts of the Equipment Indicated, Also Some of the Dimensions.

In addition to its use with beacon stations, this system can also be used for determining the position of another ship. This makes it possible for vessels so equipped to pass each other safely during a heavy fog.

We see from the foregoing that it is not sufficient to just determine the direction of a signal. It is also necessary to know the position of the source, or the strength of the incoming signal. Therefore, use is made of the uni-directional properties of a loop, and an antenna. When this is done, the loop is no longer merely a directional finder, but is a radio compass.

Bi-Lateral and Uni-Lateral Methods

There are two methods of using the radio compass loop. First, the "bi-lateral" method, consisting of finding the direction of the oncoming electromagnetic waves from the transmitter by turning the loop until the signals in the phone are a minimum, or silent. In this method, the position of maximum signals covers a much wider turning position of the loop than does the position of minimum. The minimum signal is exactly at right angles to the direction of the received electromagnetic waves. However, it has the disadvantage of being "bi-lateral"—that is, it indicates either one of two points, exactly opposite each other. Usually, the radio operator on board ship has a sufficient idea of his whereabouts to know that the signals could be coming from only one of the two directions indicated. But this is not always the case. When this point is uncertain, the "uni-lateral" method is used to determine the approximate direction of the signals, after which a sharper tuning in this direction is obtained by use of the minimum tuning method.

The "uni-lateral" method uses the loop antenna in conjunction with a regular elevated antenna, such as shown in Fig. 12. This method is based on the polarity phase of the loop. In the bi-lateral method, when the loop was turned to a position where signals were loudest in the phone, the loop was standing parallel to the direction from which the signals were being transmitted, and the question was to know from which side of the loop or coil they were coming. When the loop was turned completely around, the signals were as loud as before. In turning the loop around, the direction of the current in the loop was reversed, but the received signals were still at maximum strength. In other words, the polarity of the loop was reversed and in the bi-lateral method, practical use of this fact was not made. But this is the foundation of the "uni-lateral" method.

By inductively coupling the loop antenna, L, to the elevated antenna, A, through the coupling coils, L1 and L2, some of the received energy of the elevated antenna is conveyed to the loop antenna. Therefore, we have a means of taking advantage of the relative polarity of the elevated antenna current and the loop antenna current. When the loop antenna is in such a position that the currents from both sources of transmission are flowing in the same direction, the signals heard in the telephone will be louder than without the induced elevated antenna current. But when the two currents oppose each other, turning the loop antenna parallel with the oncoming electromagnetic waves will only produce very weak signals. This is because the elevated antenna current does not reverse with the reversal of the loop antenna. By this method, it can be seen that the approximate direction of the transmitter can be obtained.

However, as the maximum signals cover a wider range of the compass dial than the minimum, this is never accurate and the loop must then be disconnected from the elevated antenna coupling and used separately to determine the exact direction of the oncoming signals by tuning the signals out.

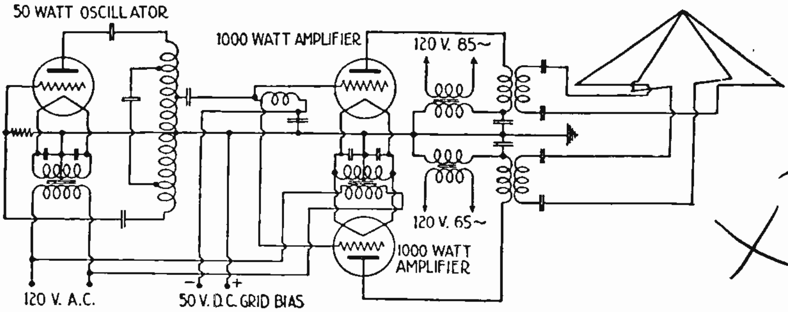

Fig. 15.—Schematic Diagram of Radio Beacon Transmitter Developed by Radio Service, U. S. Bureau of Standards.

It must be understood that the elevated antenna and the loop antenna to be used for uni-directional radio compass work must be calibrated together. A pointer on the shaft which turns the loop antenna must be arranged in such a position that it indicates the direction of a known transmitting station, when the two antennas give the loudest signals. After this, with the two used together and loudest signals heard, the pointer will show the direction from which the signals are coming. By varying the coupling, L1 and L2, between the elevated antenna and the loop antenna, the current can be controlled. Too much antenna current will overcome the energy picked up by the loop, and make it difficult to determine the direction of the loudest signals.

Description and Operation of a Kolster Radio Compass

A typical shipboard radio compass installation is shown in Fig. 13. In the drawing shown in Fig. 14, you will find the details of a complete installation, with the important parts of the equipment indicated. A suitable loop frame is wound with several turns of special radio frequency wire to form a coil. The frame is mounted edgewise upon a vertical hollow shaft which is in turn supported on a ball thrust bearing for ease in turning. The coil is completely enclosed within a circular housing, so that it is entirely free to rotate, even under the most severe conditions of wind and waves. The housing also protects the coil from mechanical damage. The coil and housing may be mounted at any desired height above the deck, and are rigidly supported by four braces clearly shown in Fig. 13.

The shaft on which the coil is supported extends through a suitable housing to the room in which the compass is located. The leads from the coil pass through the tubular shaft to collector rings. From the collector rings, the leads pass through a conduit to the compass receiver which is located in the upper part of the compass binnacle. At the lower end of the shaft is attached a pair of sight wires which travel over a compass card, or degree scale, by means of which the angle between the station upon which the bearing is taken, and magnetic North, true North, or the ship's direction (depending upon the type of installation) can be read directly. The sight wires are not rigidly fastened to the shaft, but are connected to it by a simple mechanical device which automatically corrects any error caused by the influence of the ship's hull and rigging on the apparent direction of the incoming radio waves. This device is called the "automatic compensator."

As the coil is rotated by a hand wheel, the characteristic signal from the beacon station will be heard in the phones with a gradually varying degree of loudness, until the plane of the coil is at right angles to the direction of the incoming electromagnetic waves. At this point, the signal fades out entirely. This position of silence is very critical and sharp, and indicates with great accuracy the line of the direction of the waves. By means of cross bearings on two or more stations, or by several bearings on a single station, with the distance logged between bearings, the position of the ship can be determined by simple triangulation, with an accuracy equal to sight bearings on visible fixed objects.

In obtaining a compass bearing, it is essential to eliminate the so-called "antenna effect" of the compass coil. This is accomplished by a simple adjustment on the receiver panel.

It is often desirable to know the true direction from which the waves are approaching, while the bearings obtained above do not indicate more than their line of travel. Although in the majority of cases this direction is known to the navigator, the occasion may arise wherein the location of the signalling station is not known—for example, the position of another ship at sea. To obtain the true direction, it is necessary to unbalance the

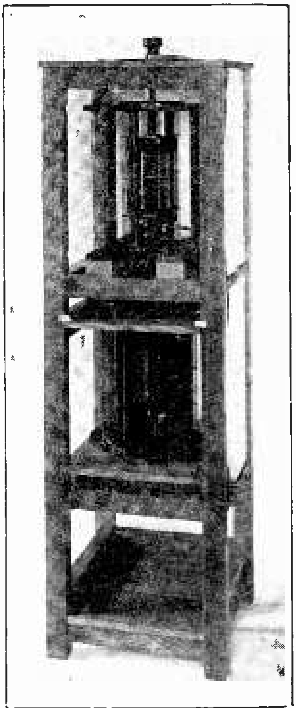

Fig. 16—Goniometer Used to Shift Course in Any Desired Direction.

compass coil by exaggerating the antenna effect. This is done by connecting a small antenna, usually not more than 20 feet long, to the receiver through a suitable switch, also located on the receiver panel. Normally, this uni-directional switch is open when taking a bearing, but when the true direction is desired, the operator closes the switch and turns the compass coil to the position of maximum signal strength. At this point, the plane of the coil lies in the direction of the signalling station and points toward it, as indicated by an index pointer provided for that purpose.

The radio compass receiver is located directly beneath the compass, as shown in the various photographs, and utilizes a circuit especially designed to give maximum sensitivity and selectivity, together with simplicity. The receiver contains eight tubes, so operated that they are equivalent to four stages of radio frequency amplification, a detector, and two stages of audio frequency amplification. The receiver is designed to operate over a wave-length range of approximately 550 to 1050 meters.

The A and B batteries for the filament and plate, respectively, are located beneath the receiver at the bottom of the binnacle. The A battery consists of an Edison storage battery which is designed for reliability and long service. A double pole double throw switch is located within the phone compartment directly beneath the receiver, by means of which the battery may be connected to either the receiver or to the ship's mains for charging.

A charging resistor, to limit the current, is mounted in some suitable location in series with the ship's supply.

The antenna switch and signal light shown in the illustration are for the purpose of assuring that the ship's main antenna is open when bearings are being taken. This antenna switch is normally located in the ship's radio room under the control of the radio operator. Red lights on the base of the switch and on the radio compass binnacle indicate that the antenna switch is open. If the light on the compass is not lit when it is desired to take bearings. the navigator communicates with the radio personnel and sees that the antenna switch is opened before operating the compass.

The principles of operation of the R. C. A. and Federal Radio Directional Finders as used on board ship are practically the same with the exception of the receiving apparatus. The R. C. A. compass uses a Super-Heterodyne receiver, while the Kolster radio compass uses a very sensitive tuned radio frequency receiver.

There are several methods of making the installation on shipboard, depending somewhat on physical conditions and circumstances. The apparatus may be mounted at any convenient place on the upper deck reasonably clear of riggings, stacks and bulkheads. It is desirable that the coil be at least three or four feet from all metallic structures. Logically, the coil should be overhead with the indicator directly beneath. The most favorable installation on a large vessel is to place the coil over the chart room on the flying bridge and on the fore and aft center lines of the ship. In this case, the indicator and receiver are conveniently located in the chart room. On the other hand, the coil can be mounted on the roof of the wheel house

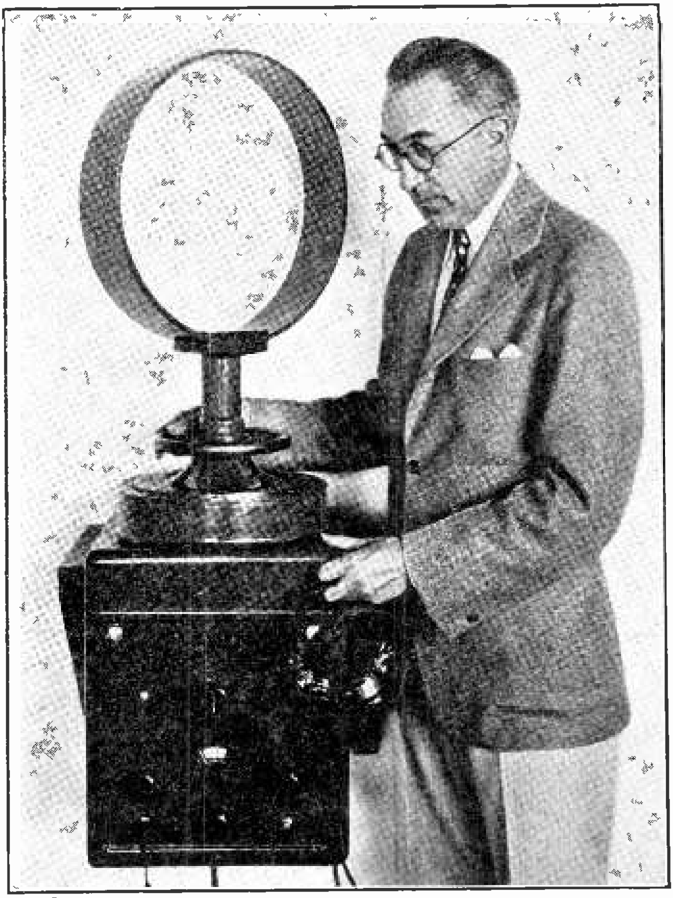

Fig. 16-A—Dr. F. A. Kolster, Inventor, Inspecting an Installation of a Small Radio Compass on a Sea Skiff.

and the indicator inside over the steering compass, or the coil can be placed on the roof of any deck house with the indicator located in any available room below. In such case locations are not available, it is possible to install the entire equipment within a frame work on the open deck.

When a radio compass is first installed on board ship, it is necessary that a careful calibration be made to correct certain constant errors due to a distortion of the approaching wave front caused by the metallic mast of the ship and any conducting material in the vicinity of the compass coil.

The dimensions shown in Fig. 14 give an idea as to the required installation space of such apparatus.

For some years, only one type of Kolster radio compass has been manufactured, which on account of its size and cost has been better suited to the larger vessels.

The Radio Beacon Service is available to all types of vessels, both large and small, therefore, it is particularly desirable that small vessels in coastwise navigation should be equipped with a suitable Radio Compass.

The Federal Telegraph Company has, therefore, developed a small, compact, direct-reading radio compass which can be readily installed on the smallest vessels at a very moderate cost.

With this small radio compass, accurate bearings on any of the established radio beacons can be taken over distances up to 25 miles or more, depending upon the power of the transmitting beacon, thus enabling small crafts in coastwise navigation to take full advantage of the Radio Beacon Service in fog and thick weather, enabling them to avail themselves of an important aid to navigation and to enjoy equal safety at sea with the larger ocean-going steamers.

AIRCRAFT RADIO BEACON DEVELOPMENTS

We shall now discuss the "ways and means" of aircraft radio-beacon systems.

The possible applications of directional radio devices to aerial navigation may be broadly classified in three different groups, namely, "directional radio receivers on aircraft," "directional receiving stations on ground," and "directional transmitters on ground."

Radio communication between aircraft and ground developed during the World War. Such communication is a powerful aid to air navigation, since in conditions of storm or poor visibility, the pilot can be informed of conditions along his route or told where a safe landing can be made. The first attempt to develop a radio device as an actual navigation instrument involved the direction finder, which had been developed and used with great success in marine navigation. It was not possible to duplicate this success in air navigation because of the engine ignition system interference, a limited space, excessive noise. Also, preoccupation of the pilot diminishes the possibiity of taking useful bearings in airplanes with direction finding coils.

The reverse procedure (use of direction finders on ground) is employed with a certain amount of success abroad. However, only aircraft having complete transmitting and receiving sets can receive aid from this system. This eliminates the small airplane. Furthermore, errors in the bearings taken are apt to result with this system, owing to the inclination of the airplane transmitting antenna.

Efforts to develop a radio navigational device was made by the U. S. Bureau of Standards in 1921. Working on the air navigation problem at the request of the Army Air Service, the Bureau devised the cross-coil or double-beam directive type of radio beacon.

This beacon consists essentially of two separate coil antennas, set at an angle with each other. These send signals

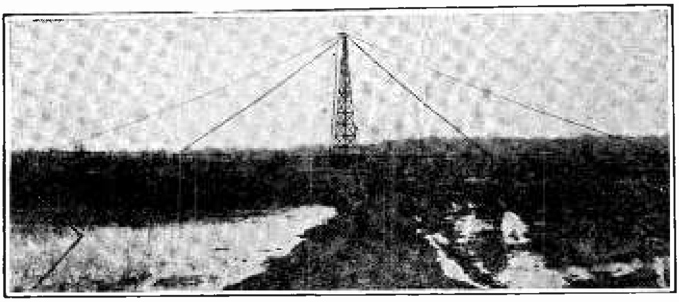

Fig. 17—Radio Beacon Station at College Park, Md.

at alternate intervals. Equality of signal strength from the two antennas is obtained along a line bisecting the angle between the plane of the two antennas. The advantage of this system is that its use requires nothing more than a radio receiving set on the airplane.

Aircraft Radio Beacon Transmitting Apparatus

The directive radio beacon station is usually located at an airport just off the landing field. This transmitter, as stated previously, employs two loop antennas, crossed at an angle of 90 degrees. Each antenna emits a set of waves which is a maximum in its plane, and a minimum at right angles thereto. Both antennas transmit 290-kc. waves, but modulated at two different frequencies.

A master oscillator producing 290-kc. current feeds two

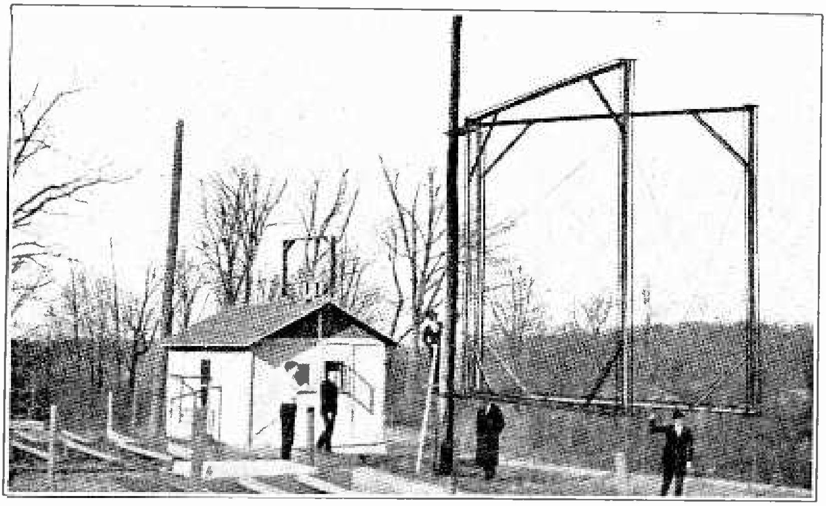

Fig. 17-A—Experimental Type of Double-Coil Antenna, Arranged to be Rotated About the Telegraph Pole as an Axis.

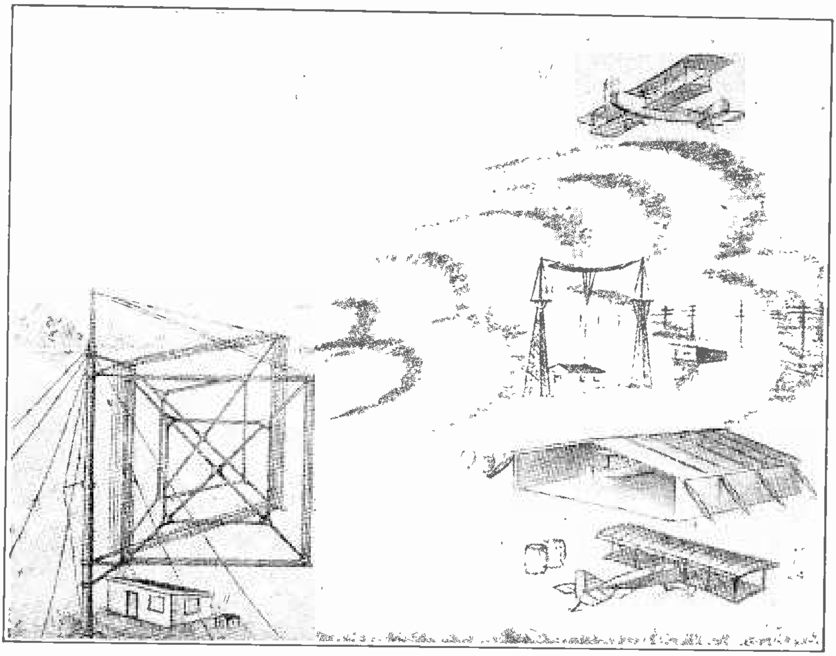

Fig. 17-B—This illustrates the Use of the Directional Transmitter in Connection With an Aeroplane Field.

power amplifiers. These are modulated by two different low frequencies. Their output goes separately to the two loop antennas. Figure 15 is a circuit diagram of the radio transmitter in simplified form. The two loop antennas terminate in tuning condensers and coils, as shown in the diagram. They are both tuned to 290-kc. and so adjusted that there is no coupling between them. The coils are coupled to the plate circuits of the two 1000 watt amplifiers.

A radio frequency voltage is applied to the grids of the two amplifiers from the 50 watt master oscillator operating at 290-kc., and direct voltage is applied to the plate.

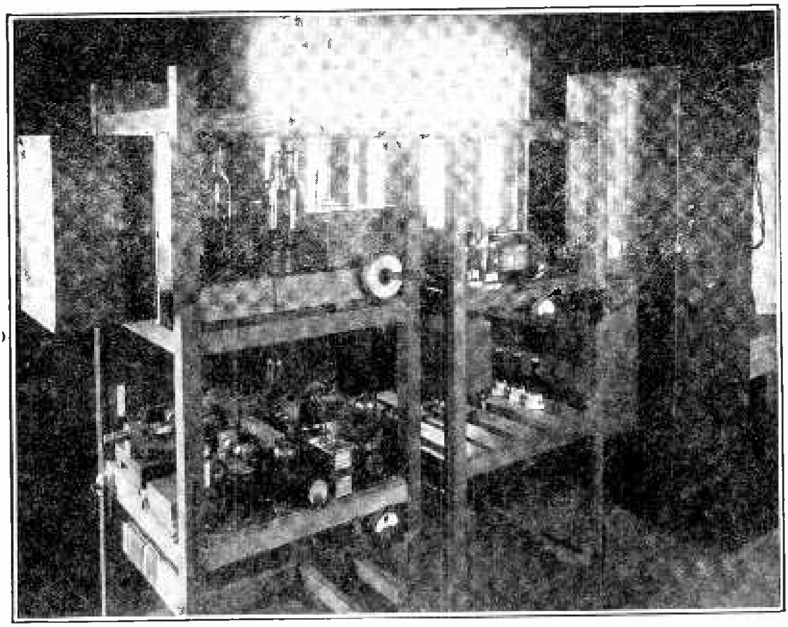

Fig. 18—Interior of a Beacon Transmitting Station.

The plates of the amplifier tubes are supplied with high voltage alternating current through transformers. One is connected to a source of 85 cycle voltage, and the other to a source of 65 cycle voltage. These are the two modulation frequencies to which the reeds of the visual indicator installed on the aircraft are tuned. Such visual indicators will be taken up later on in this text book. Each power amplifier passes radio frequency current every alternate half cycle, the frequency being 85 or 65 cycles. This occurs each time the plate is positive. The completely modulated output from one amplifier supplies power to one of the antennas only, and the other amplifier supplies only the other antenna.

The use of a common master oscillator prevents any shift in the indicated course, due to tuning of the receiving set. This might occur if two master oscillators were used, if they differed slightly in frequency.

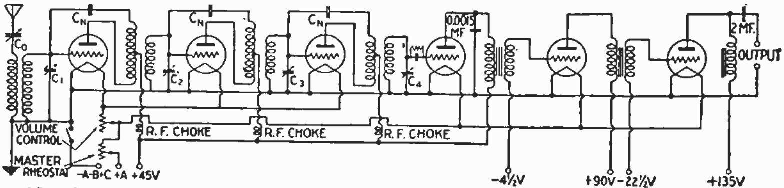

Fig. 19—Schematic Diagram of Aeroplane Radio Receiver Used to Receive Radio Beacon Signals and Weather Reports.

A number of other methods for modulating the carrier frequency at the low frequencies required are possible and have been used. The method just described involves the supplying of plate power directly to the amplifier tube at the low frequencies desired. This method was not found entirely practicable because the constancy of the low frequencies depends upon the steadiness of the frequency of the power source

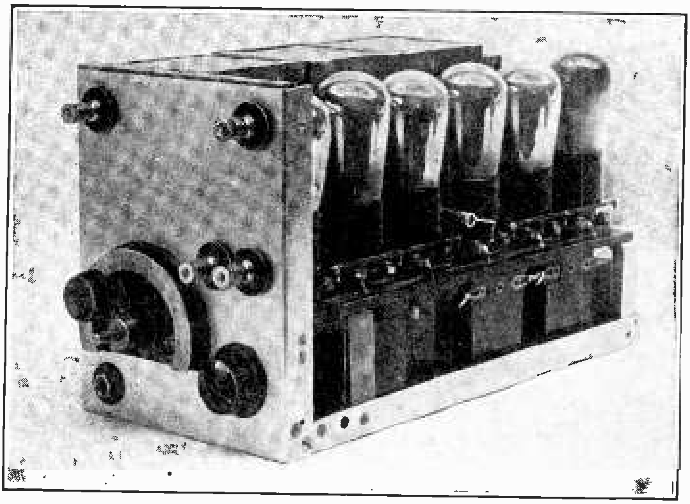

Fig. 20—Unicontrol Receiving Set for Beacon and Telephone Reception.

available, which varies somewhat in most cases. Even with a steady source available, alternators with synchronous motors of special design to drive them would be necessary.

The vacuum tube oscillators controlled by tuning forks which supply sufficient voltage to enable grid or plate modulation of intermediate amplifiers have been developed, and solved the difficulty of keeping the low frequencies steady.

In the "grid modulation" method, the modulating frequency is impressed on the grid of one of the amplifier tubes. With the plate modulation method, the low frequency voltage is applied to the grids of the modulating tubes, the plates of which are connected to the output of one of the amplifiers in a circuit arrangement analogous to that of the ordinary method of plate modulation employed in broadcasting stations. Both methods give satisfactory performance, although the plate modulation scheme has some advantage in that less distortion in the wave form is introduced.

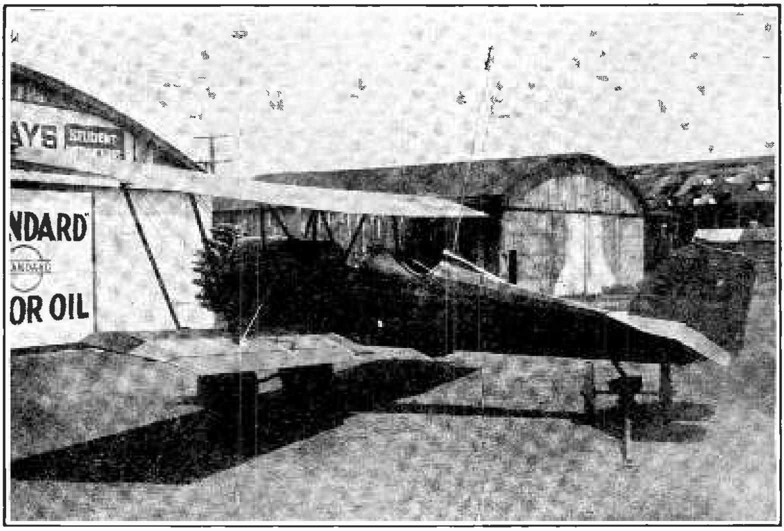

Fig. 21—Pitcairn Mailwing Airplane, Showing Vertical Pole Antenna.

When the beacon is to be used for air routes in several directions, a "goniometer," not shown in Fig. 15, must be introduced. This is a coupling arrangement between the two antennas and the amplifiers, the rotation of which is equivalent to rotating the antenna. The goniometer designed for use with this apparatus is shown in Fig. 16. It has two pairs of coils, each pair consisting of an 8 turn rotor and a 32 turn stator. The stator coils are fixed at right angles to each other and so are the rotors. The rotation of the rotor coils, with respect to the stator coils, orients the path marked out by the beacon in any desired direction. At airports where several courses intersect, the beacon course can be set successfully on the several courses for fixed time intervals. The simultaneous serving of two or more courses with a single beacon appears possible. Extensive work is now going on to incorporate this feature into the beacon system.

Aircraft Receiving Equipment

The beacon system can be used with any receiving set which operates at the frequencies used; it merely replaces the telephone receivers by a simple reed indicator unit. There are however, special conditions involved in receiving on an air-

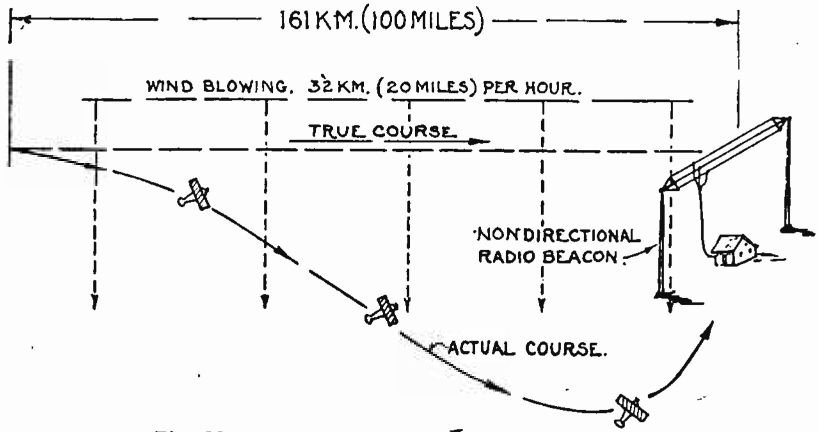

Fig. 22—Effect of Wind Drift on an Aeroplane.

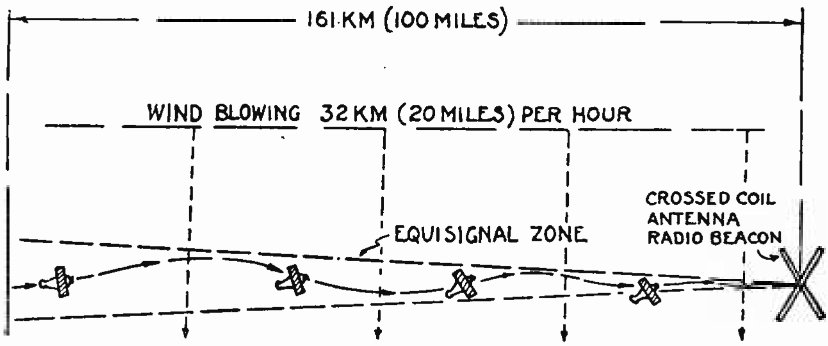

Fig. 23—Method of Eliminating Effect of Wind Drift on an Aeroplane By the Use of a Cross-Coil Antenna Radio Beacon.

plane, and the Bureau of Standards has developed special receiving sets in order to use the beacon system under the most advantageous conditions.

The receiving set designed weighs less than 15 lbs. and the auxiliary batteries weigh an additional 10 lbs. The receiving set operates in the frequency range from 285 to 350-kc. and is used to receive either the beacon signals or radio telephone or telegraph messages. The circuit diagram is shown in Fig. 19.

This receiver is provided with interstage shielding as well as shielding against the extraneous interference. The selectivity of the set designed is supplemented by the great selectivity of the reed vibrators, which help greatly in reducing interference. The set has remote control arrangements for tuning

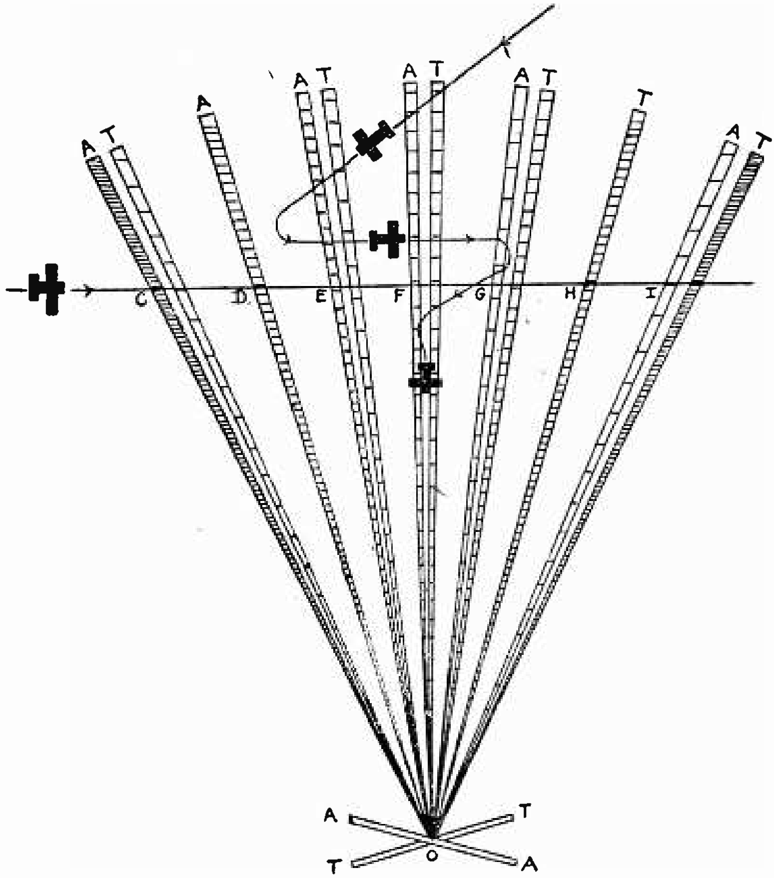

Fig. 24—This Illustrates the Method of Guiding an Aeroplane by the Equisignal Zone Method.

and volume, so that the set itself can be out of the way in the tail of the airplane.

The development of receiving sets having the necessary sensitivity made possible the use of a new antenna system on airplanes. It consists of a metal pole about 10 feet long, extending vertically from the fuselage. The use of a trailing wire antenna with its attendant inconvenience and possible danger is thus eliminated. A great advantage of the vertical pole antenna is that it is entirely non-directive, and as a consequence, night direction variations in the beacon course are considerably reduced. In addition, since this type of antenna is not affected by the horizontal component of the electric field radiated by the beacon, a region of zero signal strength is met with, directly above the beacon power (where no vertical field exists). This serves quite effectively to exactly locate the flying field. With the trailing wire, it was a very difficult feat to guide an airplane right to the beacon, and it became impossible when the side wind produced a slight slant to the antenna.

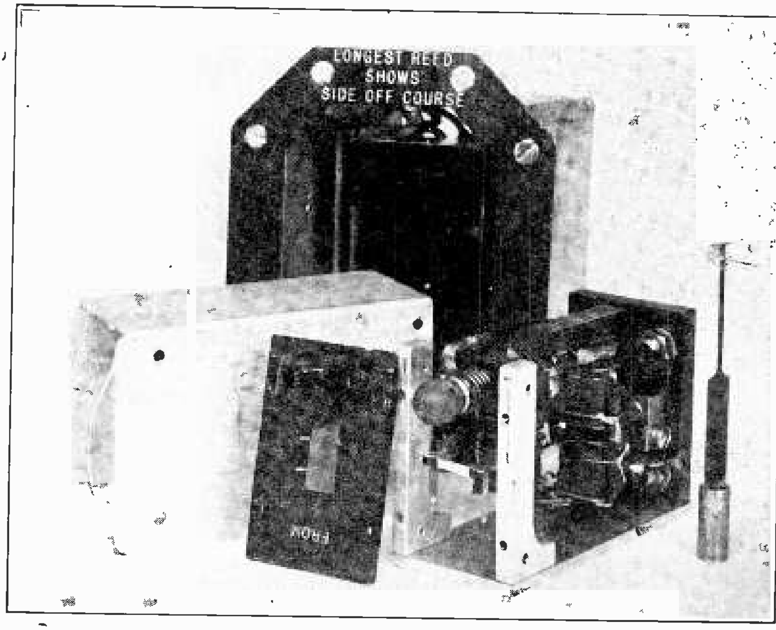

Fig. 25—Visual Reed Indicator Unit (Cover Removed.)

Therefore, the vertical pole antenna makes it very simple to fly directly towards the beacon. Now, the beacon can be located within 100 feet, when the airplane is not over 1000 feet above it. This is a most valuable aid to landing in fog.

Reed Type Visual Indicator

Figure 25 and Fig. 26 show the reed indicator units. They are designed to match the output impedance of the receiving set and give full scale deflection with 10 volts across the terminals. This reed indicator unit consists of two vibrating steel reeds. Their vibration gives the visual indication, while they, themselves, provide the necessary tuning to the two modulation frequencies.

The indicator is very simple and rugged. It is mounted on the instrument board in front of the pilot, and electrically connected to the receiving set output in place of the telephone receivers. It consists of a set of coils through which traverse the audio output currents of the receiving set acting on a pair of short steel strips or reeds. These two reeds are tuned to the beacon modulation frequencies, 65 and 85 cycles per second.

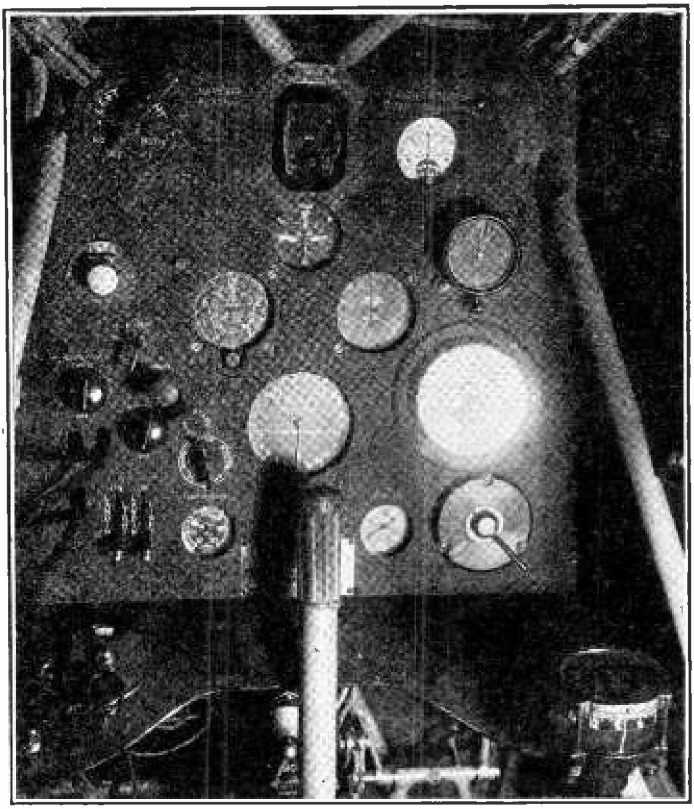

Fig. 26—Photograph Showing a Reed Indicator Mounted on an Airplane Instrument Board (top center).

When the beacon signals are received, the two reeds vibrate. Since they are tuned to the two modulation frequencies used at the beacon, they indicate the equality of received signals from the two loop antennas. The p ts of the reeds are white against the dark background so that when vibrating they appear as vertical white lines. For use in night flying, suitable indirect lighting of the reed strips is provided.

When the two white lines are equal in length, the airplane is on its course. A deviation from this course to the left increases the deflection of one reed, and decreases that of the other. The reverse is true if the airplane deviates to the right. To return to the course, the pilot turns in the direction of the shorter reed. By piloting the airplane so that the two lines are always of equal length, he remains on the indicated course. The reed indicator is very sensitive, requiring less than 2.5 volts across the indicator terminal for full reed deflection.

A phenomenon quite common to mechanicallly tuned devices is the change in their vibratory frequency, caused by changes in the surrounding temperature. This phenomenon was observed in the case of the vibrating steel reed. A simple compensating device has been perfected which nullifies this effect, making the reed frequencies entirely independent of temperature.

The Bureau of Standards has experimented with a number of possible visual indicator systems. One was by using a neon lamp device. The output of the receiving set was fed into two selective circuits containing the neon lamp. Both lamps lighted indicated the position of the course location. One lamp lighted meant off course on the side corresponding to the frequency used to light it. This method was abandoned after several trials because of the need for too many amplifiers to operate the lamp. Neither could the distance deviated from the course be told, as the lamps were either on full, or not at all.

It can be seen from the foregoing that with the radio beacon made practical and dependable, air route operations enter a new era of regularity and safety. Most of the trips which are now omitted, or undertaken only at great risk, can be confidently made.

For those not familiar with the navigation of airplanes, the following should be of interest:

The method of aerial navigation called "instrument flying" is in common use. When the pilot cannot see the earth below, he forgets the outside world, and, concentrating all his attention on his instruments installed on the airplane instrument board (see Fig. 26), he then navigates his craft from the information these instruments convey. For example, one instrument tells him his elevation, another his speed, another whether he is turning or flying straight away, and his compass indicates his general direction. But, accurate as all these instruments may be, they do not tell him if he is drifting sidewise due to a cross-wind, nor do they tell him exactly at what speed he is travelling, because there may also be a head or tail wind to slow him down, or to speed him up. Thus, while instrument flying may enable a pilot to keep his craft at a safe altitude and in a generally correct direction, the hazard of getting farther away from the course into strange, unfamiliar, and possibly dangerous areas is ever present.

What instrument flying has hitherto lacked is precisely supplied by the radio beacon system, because with its use the pilot can always know his location.

TEST QUESTIONS

Number Your Answer Sheet 49 and Add Your <u>**Student Number**</u>

1. What important piece of apparatus in Radio makes direction finding possible?

2. What is the position of the plane of the coil antenna for maximum and minimum signal intensity?

3. State the two methods of using a direction finding loop.

4. What is a Radio Beacon Station?

5. State the meaning of bilateral and unilateral characteristics in Radio compass work.

6. Draw a circuit diagram of a Radio Beacon transmitter.

7. Why must a Radio compass be calibrated when installed aboard a ship?

8. Name the three classes of aircraft directional Radio devices.

9. Draw a diagram of an airplane receiving circuit used for Radio Beacon signals.

10. What is the advantage of using a vertical pole antenna on airplanes.

RADIO BY MAIL

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