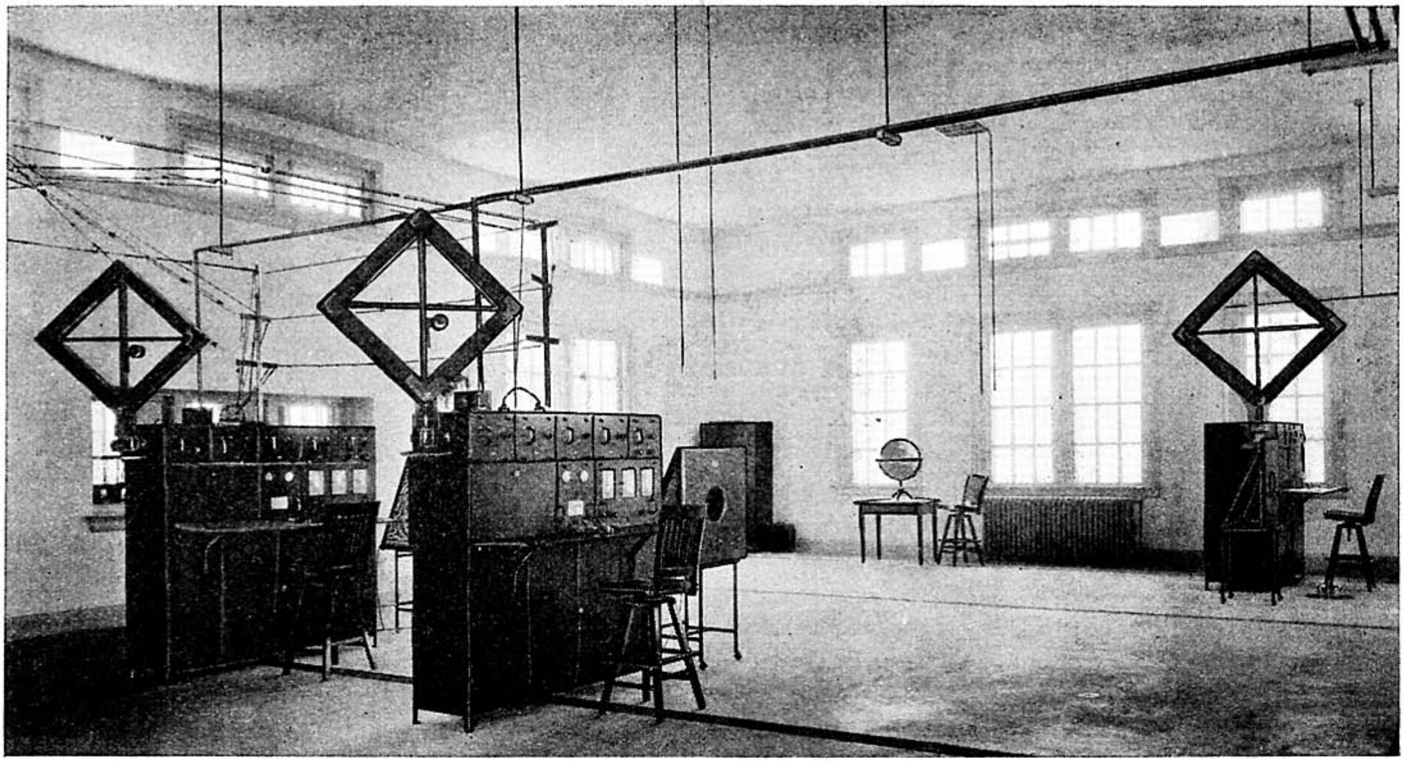


Fig. B. *One-half of the main instrument room of Uncle Sam's "air police." Every point of the compass is under inspection, at will.*

GRAND ISLAND

(PART

SINCE the advent of Radio, there has been an increasing need for some system of accurately checking the frequency of transmitted radio waves. Before the general use of crystal-controlled transmitters, calibrated wavemeters served their purpose very well. However, in order to have any regulation of radio transmitters *it is absolutely essential that the methods of measuring used by the regulating agency be far more accurate than any method used by the stations involved.*

THE discovery of the great value of high frequencies in radio made the problem of frequency measuring an international, as well as a national one.

Several years ago, Mr. S. W. Edwards, then Supervisor of Radio at Detroit, Michigan, foresaw the value of a centrally located monitoring station, supplemented by several strategically located secondary standards, and bent his efforts toward securing such a system for the Radio Division of the Department of Commerce.

The appropriation of approximately $400,000 for land and buildings having been secured, the next problem was to draw up a primary standard and associated equipment, and eight secondary standards and their associated units.

It was then found that few companies were able to build measuring equipment of the required accuracy and receivers of the necessary sensitivity and selectivity. The award was finally made to the Westinghouse Electric & Manufacturing Company, and a great deal of the equipment now used has been manufactured by them.

Location of Station

With the manufacture of equipment well under way, the next move was to secure a location for the central frequency monitoring station. An extensive field strength survey was made of the middle-west, and finally Nebraska was chosen as the most likely state in which to locate the station. Several factors prompted the choosing of Grand Island as a location. Chief among these was, first, it is centrally located in the United States; second, the level nature of the terrain makes for receiving conditions approaching the ideal; and third, the action of the Grand Island Chamber of Commerce in selling the government fifty acres of land for one dollar.

The exact location of the station is six miles west of Grand Island. It was deemed necessary that the station should be several miles from any center of population, in order to get away from "man-made static." Considerable care was necessary in planning the station itself. As it is an isolated plant, it must be equipped with a good water supply, power supply, and heating and sewage-disposal systems. In order to satisfactorily accomplish the work required of the station, it was also necessary to build an extensive

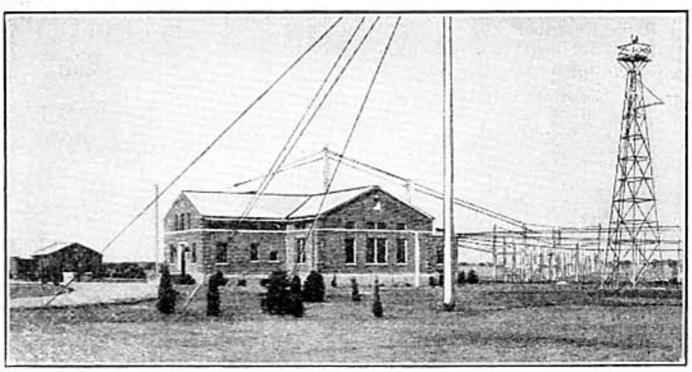


Fig. A
The main building, garage and engine room, 'plane beacon, and antenna system at the U. S. Monitor Station, Grand Island, Nebr.

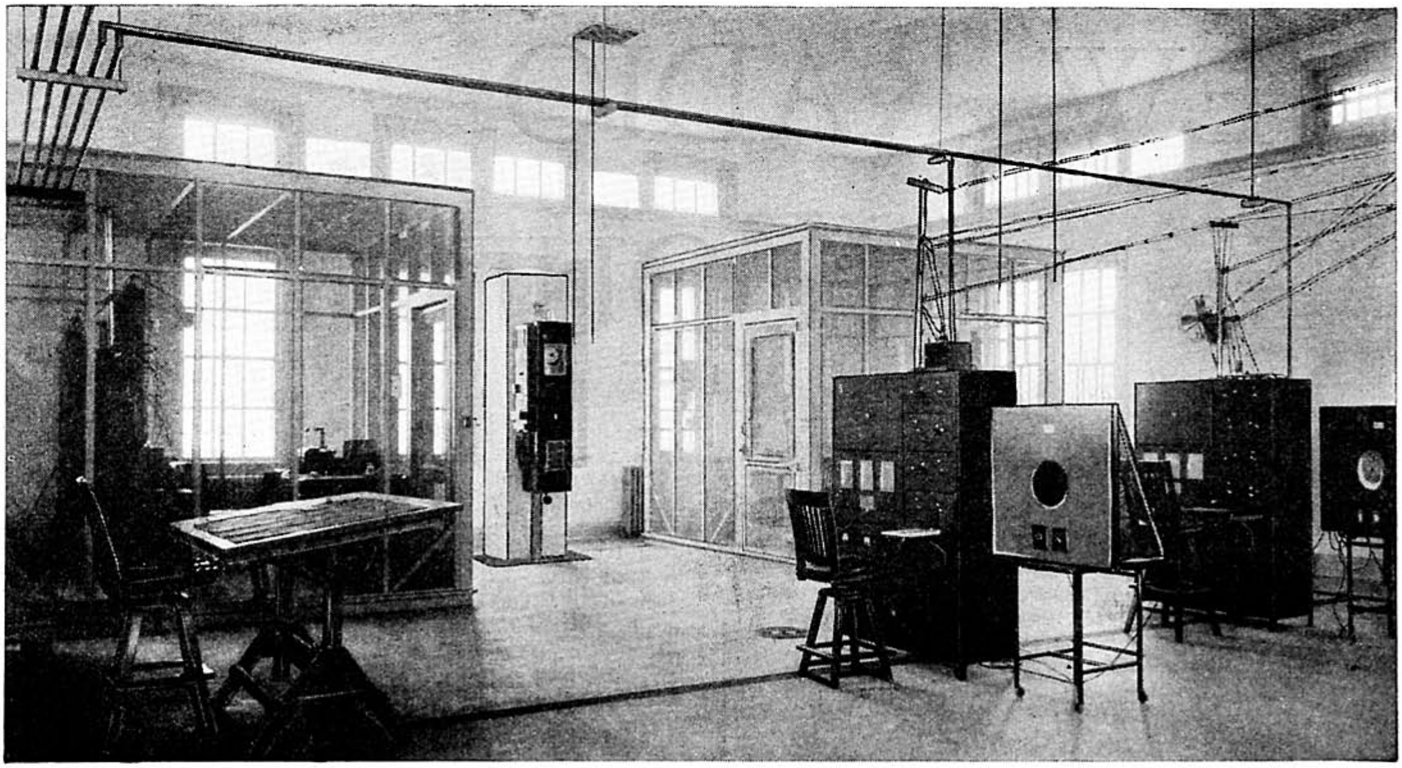


Fig. C. *One-half of the main instrument room of the U. S. Government's broadcast station frequency monitor system at Grand Island.*

MONITOR STATION

I)

antenna system.

A visitor cannot help but be somewhat impressed by the amount of detail that has gone into the construction of this Frequency Monitoring Station, and can readily see that to properly man all of this highly scientific equipment calls for a personnel of great ability who are well trained in their particular phase of the work. At present, there are 27 people employed at the station. In addition to the Manager (Mr. Benjamin Wolf) and Assistant Manager there are eight engineers, all of whom hold B.S. degrees in electrical engineering or have had wide radio experience, eight radio operators loaned the Radio Division by the Airways Division of the Department of Commerce, four Diesel engineers, one chief clerk, two stenographers and two janitors. This is enough to operate the station 16 hours a day. It is hoped that funds will be available later to add enough personnel to operate 24 hours a day.

It was mentioned in the first part of this article that in planning the station, the design engineer was confronted with the usual problems of an isolated plant, many of which were outside the radio field. Among these were the buildings, heating and sewage-disposal systems, and primary power supply. In this work, the help of the Bureau of Yards and Docks of the Navy Department was sought and obtained. The architect was F. W. Southworth of the Navy Department.

Buildings and Power Supply

There are two buildings, a main building shown in Fig. A, and a combination engine room and garage. The main building houses the radio equipment and heating plant. It is built of red brick and in the shape of a cross. The main floor has a motor-generator room, a battery room, work shop, main instrument room which is 72 x 35 feet, an office and a kitchen. The second floor has a dormitory and small office and the basement has a storeroom and boiler room. The kitchen and dormitory are for emergency purposes in case the personnel are storm bound.

The other building is built also of red brick and is divided into a four-car garage, a work shop, and engine room.

The primary power supply is two 40-H.P. Diesel engines driving 240-volt, 60-cycle, 3-phase alternators. Diesel engines were used in order to eliminate ignition interference. The engines are Fairbanks-Morse 3-cylinder, 2-cycle Marine type. Two 2000-gallon fuel oil tanks, buried outside the engine room, furnish fuel oil for both the Diesel engines and the oil burning furnace in the main building. The power from the alternators is made available in the main building through underground lines to a distributing panel in the motor-generator room. Motor-generator sets and rectifier units provide the necessary D.C. for battery charging. The standards and receivers, shown in Figs. B and C, are all operated from battery supply.

In the engine room beside the engines and their associated equipment, is a motor-driven pump which is capable of delivering 125 gallons of water per minute. The capacity of the well itself is in excess of 500 gallons a minute. This well is used to furnish the general water supply as well as an irrigation supply for seven

(*Continued on page* 489)

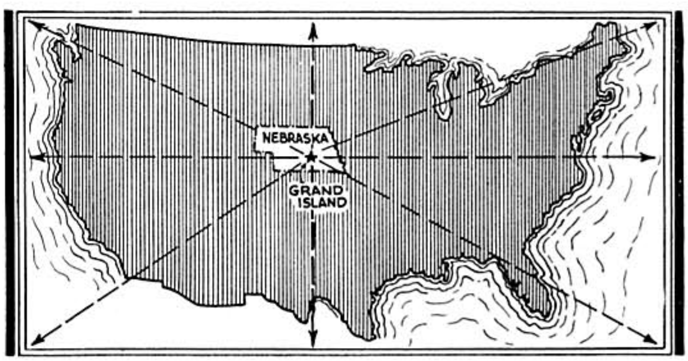


Fig. 1
Grand Island, Nebraska,—the most desirable spot in the United States for the reception of all our broadcast station programs.

GRAND ISLAND MONITOR STATION

(*Continued from page 461*)

acres of ground surrounding the buildings. This acreage has been landscaped and in a few years should be one of the beauty spots of Nebraska. The Stars and Stripes floating from a seventy-foot flag pole in front of the main building advertises the fact that this is a Federal institution.

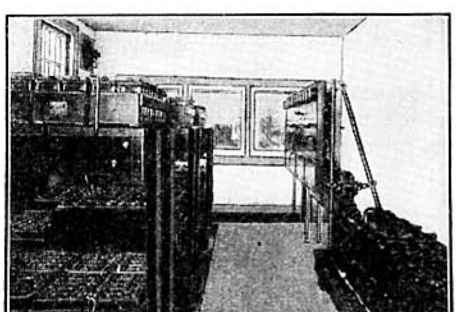
The numerous fifty-foot poles and the antenna network supported by them have been recognized as a definite hazard to aircraft. For this reason, a sixty-foot tower with a 2-million candle power revolving red beacon mounted on top, has been erected on the grounds. A white course-light pointing directly to the local airport is mounted just below the red beacon.

Every effort has been made in constructing the station to eliminate inductive interference. All motors used at the station are of the induction type. All power leads are shielded. Copper mesh is incorporated *within the walls, ceiling* and *floor* of the motor-generator room. All outside power leads are underground. The telephone cable enters the station through nearly ¾-mile of underground duct. This is a 26-wire cable and furnishes ample facilities for local and long-distance telephone communication.

The Sequence of Measuring Station Frequencies

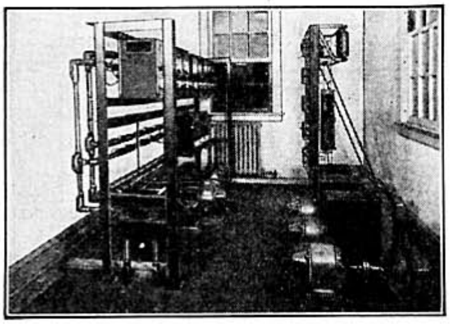
Each measurement goes through four operations before it is turned in to the office. First, the station must be intercepted and identified by the receiving operator; second, the *measuring sheet* goes to the *measuring booth* where the station is measured and the sheet stamped in order of its submittal; third, the final results must be calculated; and fourth, the entire sheet is checked.

All the sheets from one day's watch are turned in to the office the following morning and made up into a *report sheet*, which is sent in to the Radio Division at Washington.



General view of the battery room of the U. S. Monitor Station at Grand Island, Nebraska. The room is well ventilated in order to allow the fumes that are generated, to escape.

Already *the needs of the plant have outgrown its present size.* Many more directional antennas are needed if the station is to give the same service to all parts of the country. This necessarily means more land, more receiving equipment and more personnel. A high power short-wave *transmitter* is needed for more rapid reporting of frequency deviations. The station must



Distributing panel in one of the generator rooms at Grand Island. The generators used for charging the batteries are shown to the right of the picture.

grow and change as the radio art grows and changes. With proper support, the future of the station is bright.

Uses of the Station

The station is designed primarily for the purpose of checking the transmitting frequencies of all the broadcast stations in the United States, as well as a considerable number of foreign broadcasters. Aside from its routine task, Grand Island performs numerous other special services for the Government. It is prepared, for example, to report on radio transmission in practically any country on the globe.

Station wavelengths are measured against the Standard Precision Clock which is mounted in a vacuum chamber in a ten-ton concrete column. The Precision Clock corresponds to the standard pound, the standard foot, the standard quart, etc., in Washington, and is law to the broadcasters. Its pendulum makes one complete swing in two seconds, or covers one-half cycle in one second. This frequency is multiplied through a tuning fork and vacuum tube amplifiers to 30,000 cycles per second, from which harmonics are produced and selected to match the lowest or highest radio frequencies in commercial use.

While reception is taking place careful notes are made of weather conditions, barometrical pressure, and other items which tend to furnish information on transmitting conditions. Approximate signal strengths are noted as well as any other characteristics of the received signal. By reason of this information, it is expected that transmitting conditions under given circumstances will be predictable, and that it will be known, in a general way, what stations can be re-received under certain conditions and at what times reception will be at its best.

In the second part of this article, which will appear in the March issue of RADIO-CRAFT, the antenna system and all other available information concerning this interesting station will be given.

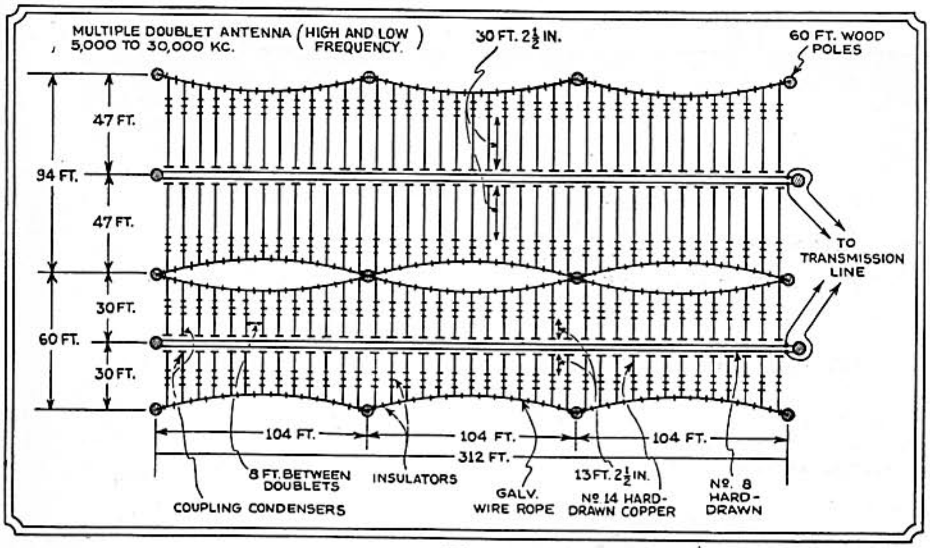


Fig. 2

The multiple doublet antenna system at Grand Island, Nebraska. The lines are terminated with a 410-ohm resistor to prevent reflections.

The antenna system used at the U. S. listening station is complete in every detail, and is fully described in the accompanying description.

U. S. *Monitor Station*

(Part II)

MUCH thought was given to the antenna systems. It was early decided that if the station were to cover international channels, it should have many directional high-frequency antennas, similar to those used by communication companies. However, the Division had a different problem on its hands than most of these companies. For the most part, the communication companies monitored only a few channels, while the Radio Division proposed to monitor the whole radio spectrum. For this reason, antennas which were both *aperiodic* and *directional* were needed, or else the cost would be prohibitive.

A Beverage-type antenna was chosen to cover the broadcast range from 550 to 1500 kc. This antenna as used at Grand Island is a single wire 1400 feet long, suspended on sixteen-foot poles spaced 100 feet apart. It points to New York City. The operation of this antenna depends upon the wave tilt. The wave tilt, in turn, is dependent upon frequency and soil resistance. Every space-wave can be vectorially divided into two components, commonly spoken of as horizontal and vertical. The horizontal component is more directional than the vertical. The Beverage antenna has the property of picking up the horizontal voltage component to a much greater degree than the vertical. In very long antennas, this ratio is about 100 to 1.

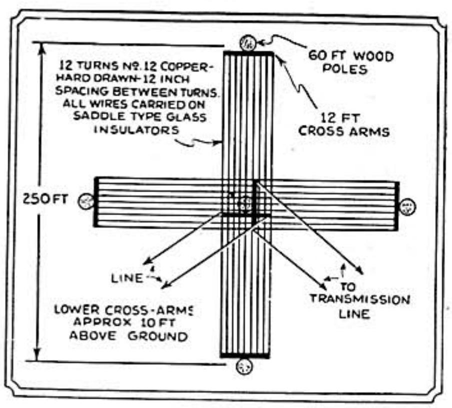


Fig. 4

The special loop antenna. Designed to cover the frequency range from 10 to 100 kc.

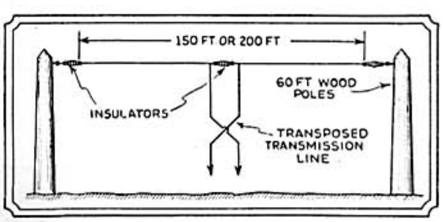


Fig. 3

Diagram of the "general purpose" antenna used at Grand Island.

As the space-wave advances over the antenna, increments of horizontal voltage are induced in each increment of wire. These voltage increments travel along the wire at very near the velocity of the space-wave. Therefore, each one adds up in phase, and the voltage wave on the wire reaches a maximum at the receiver end. The far end is terminated in a resistance equal to the surge impedance of the line so that back-end signals are dissipated, and prevented from being reflected back to the receivers. The proper value of this resistance for the Grand Island antenna was found to be 550 ohms. This is illustrated in Fig. 1.

Antenna Lengths

There are very definite lengths of antenna for maximum signal and maximum directivity. These two do not usually coincide, so that a compromise must be made. The usual method of finding the correct length for maximum signal is to set up a constant-frequency, constant-power-output oscillator, some distance from the far end of the antenna, and use a vacuum-tube voltmeter at the output of a receiver to test for maximum signal with different lengths of wire. The best length for directivity is then found by circling the antenna with the transmitter, using different lengths of antenna. The proper value of resistance is best found by setting the transmitter in the rear of the antenna and changing the resistance until a minimum signal is noted.

As the length of antenna is shortened, the ratio of horizontal to vertical pickup approaches unity, and the antenna loses its

(*Continued on page 557*)

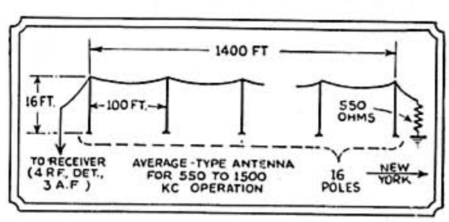


Fig. 1

The 1,400-foot Beverage antenna used at the U.S. listening station at Grand Island, Nebraska. It is terminated with a 550-ohm resistor to prevent surges.

GRAND ISLAND

(*Continued from page 527*)

directional qualities. For this reason, another type of antenna known as the "multiple doublet" was used for high frequencies. This is similar to the ones used by the R.C.A. Communications Company at Riverhead, New York. This type of antenna consists of 39 single "doublets," spaced eight feet apart, feeding a transmission line 312 feet long, which is balanced with respect to earth. This network is supported from sixty-foot poles by triatics of steel cable. Concrete counter-weights keep the network taut at all times. (Fig. 2.)

The theory of operation of this antenna is practically the same as that of the wave antenna with the exception that the voltage is fed to the transmission line at lumped intervals. If enough doublets are used per wavelength, the effect is that of a distributed feeding and a smooth building-up of voltage is obtained. As in the wave antenna, the velocity of the electric wave on the wire is very nearly that of the space-wave, providing that the impedance of each doublet is high. This is assured by making the length of the doublets short as compared with one wavelength.

The directivity of such an antenna is such that at fifteen degrees either side of center, a constant signal will drop to one-half its value directly in line with the antenna. As the vertical pickup of this antenna is small, one of its great advantages is its freedom from local inductive interference, for this type of wave is usually vertically polarized. Also, its directive qualities are useful in suppression of regional static. Back-end signals are suppressed the same as in the wave type of antenna by hanging a proper resistance across the far end of the line. The value of the resistance in this case is 410 ohms. A special carbon resistance with terminals copper-plated to either end, is used.

The signal at the receiver end of this line is fed through a transposed vertical transmission line to a long four-wire line which is electrically balanced with respect to earth. These wires are diagonally connected so that the electrical center of each pair of wires is an identical point, so, theoretically, each line has no radio pickup. In practice, it is impossible to build a perfectly balanced line. However, the pickup is small, and what there is can be bypassed to ground through astatic shields between the coils coupling the line to the receiver. The four-wire lines are terminated in dead-ending racks, outside the main building, and are jumped to two-wire transposed lines which are connected to neon cartridge lightning-arresters just outside the windows, passed through holes in the window panes, and thence to terminating blocks on the receivers.

There are four multiple doublets, two designed for a frequency range of from 5,000 to 12,000 kc., and two from 12,000 to 23,000 kc. One pair, covering the frequency range of from 5,000 to 23,000 kc., points toward Porto Allegre, So. America, and one pair toward London, England.

In addition to the directional antennas, there are five single doublets, four of which are horizontal, and one vertical. The horizontal doublets are designed to operate below the range of the multiple doublets. The "Conrad vertical" is a high-frequency antenna. It is a vertical doublet of brass pipe offset from a 60-foot pole, by insulators. The lower part has a short T-section at the end nearest the earth. This can be shortened or lengthened to balance both sides of the doublet. This antenna is designed to intercept radio waves which are vertically polarized. These doublets are connected to the receivers, through the same type of transmission line used in connection with the multiple doublets.

A 200-foot "general purpose" antenna, Fig. 3, and a low-frequency loop, complete the antenna system. The low-frequency loop deserves special mention, inasmuch as it is probably the largest radio loop ever erected for receiving purposes. It consists of two loops crossed at right angles, each loop containing twelve strands of No. 12 wire, 250 feet long by 60 feet high. Each loop is connected inside the main instrument room by a 4-wire transmission line to the stator of a goniometer; its rotor is connected to the low-frequency receiver. (Fig. 4.)

The Radio Receivers

Both loop and receiver are designed to cover the frequency range of from 10 to 100 kc. The receiver has five stages of R.F., two of which can be thrown in or out at will. Type "210" tubes are used in the R.F. and detector stages. Two sets of coils are used, one set covering a frequency range of from 10 to 32 kc., and the other from 32 to 100 kc.

Three types of receivers are used to cover the useful radio spectrum. The low-frequency receiver has been mentioned. The intermediate-frequency receivers have four stages of tuned R.F. and cover a frequency range of from 100 to 1,500 kc., by use of three sets of coils. Type "210" tubes are also used in the R.F. and detector stages of this type of receiver. The high-frequency receivers have three stages of tuned R.F. A frequency range of from 1,500 to 30,000 kc. is made possible by use of four sets of coils. Type "236" tubes are used in the R.F. stages, and a "230" in the detector stage. The audio stages of each type of receiver are alike, namely, two stages using type "841" tubes, and an output stage using an "842."

Each receiver is connected to the standard by a No. 16 gauge copper-wire inside a 1-in. brass pipe. Isolantite beads strung on the wire keep it concentrically spaced inside the pipe. The standard energy is fed to the second R.F. stage of each receiver. This has two advantages: first, the initial stage acts as a buffer preventing the standard energy feeding out to other receivers by way of other transmission lines; second, in order to get a good beat-note between two frequencies, the energy in one must closely approximate that in the other. In case of a strong signal, the first receiver stage can be detuned, thus acting as an R.F. gain control.