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LESSON TEXT No. 40

TRANS-ATLANTIC RADIOTELEPHONE AND RELAY STATIONS

Originators of Radio Home Study Courses

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Radio-Trician's
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Complete Course in Practical Radio
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TRANS-ATLANTIC RADIOTELEPHONE STATIONS

We are all acquainted with the various efforts put forth by broadcasting stations in the past three years to span the Atlantic with their respective programs. The results have invariably been the same—namely, a very weak signal capable of being tuned in upon multiple tube sets. For an equal time the American Telephone and Telegraph Company in conjunction with the Radio Corporation of America have been conducting actual transmissions day and night over long periods of time. The speech being of the same high quality as that upon a standard telephone trunk circuit.

Without a doubt this service will be greatly expanded in the near future, and many new highly paid positions will be available to those having the technical training. Services to all countries will be inaugurated, and will be the means of linking up all land line exchanges in all countries.

To the engineer who intends mastering this latest branch of radio art, there will present itself the necessity for an even more intensive training than that required to operate the usual radiophone station. This is due to the fact that in order to definitely link two vastly separated stations, apparatus of great power and efficiency must be employed.

Broadcasting differs from other types of communication in that it is a free service, and no liability attaches the station for failure to maintain schedules or reach all listeners-in. In the establishment of commercial telephone communications special care must be paid to the ability of the station as regards continuous operation.

While both the high-frequency alternator, and arc, are capable of being modulated at speech frequencies their efficiency is very low and tube transmitters are still the best radio-frequency oscillators and modulators for this purpose. At the present time their size is confined to the employment of twenty kilowatt tubes. Tubes on the order of one hundred kilowatts have been built, but they have not yet been introduced commercially. The number of oscillator tubes in parallel rarely

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exceeds ten so we find the present transmitters to be on the order of two hundred kilowatts input to the antenna.

The usual type of radiophone transmitter can only cover about sixty per cent the range of an equally powered radio-telegraphic transmitter due to the greater dispersion of energy in its larger frequency band which is required for the transmission of voice frequencies. For perfect speech transmission a band of thirty-five hundred cycles is required, and in trans-Atlantic telephony this is still further reduced to a band of from 200 to 2,500 cycles.

In the ordinary type of radiophone transmitter there are two side bands of equal amplitude from the center line of the

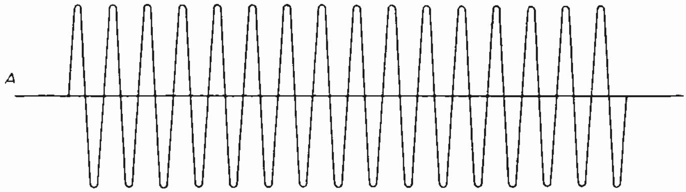

Fig. 1—Radio-Frequency Carrier Wave

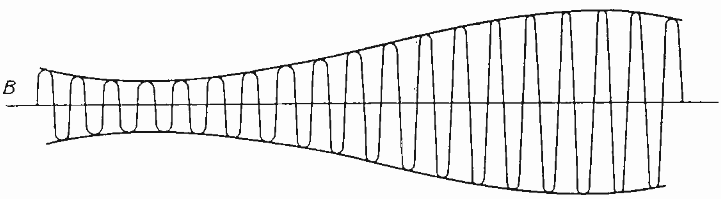

Fig. 2—Voice Frequency Envelope

carrier frequency. This is shown in Figure 1, being the emitted radio-frequency carrier and Figure 2 the voice frequency envelope. In broadcasting, where audio frequencies up to five thousand cycles are handled, the stations must have at least ten thousand cycles difference in wave-length in order not to overlap.

It is apparent that a transmitter confining its transmitted energy to a band of five thousand cycles has twice the output of one spreading over a band of ten thousand cycles. As before stated, it has been determined that good intelligible speech can be transmitted on a band from two hundred to two thousand five hundred cycles. In the ordinary type of transmitter this would require five thousand cycles for both side bands. Now

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if we eliminate one-half of this side band frequency and only transmit frequencies from two to twenty-five hundred cycles, we are restricting our emitted frequency variation, but we have increased our transmitter efficiency four times over that of the usual type. Our station of two hundred kilowatts then has the efficiency of an eight hundred kilowatt broadcasting station of the standard type.

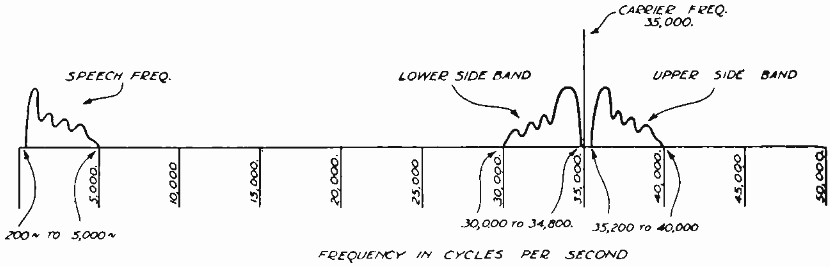

Fig. 3

Trans-Atlantic radiotelephony then has the following advantages over ordinary radiotelephony: First, it only occupies a frequency band region equivalent to that taken up by speech itself. It permits doubling the number of radio channels within a given frequency band. No carrier being transmitted, all of the energy is usefully employed, and this is a saving of two-thirds when compared to ordinary methods. By having a very narrow transmitting band extremely efficient receivers can be employed.

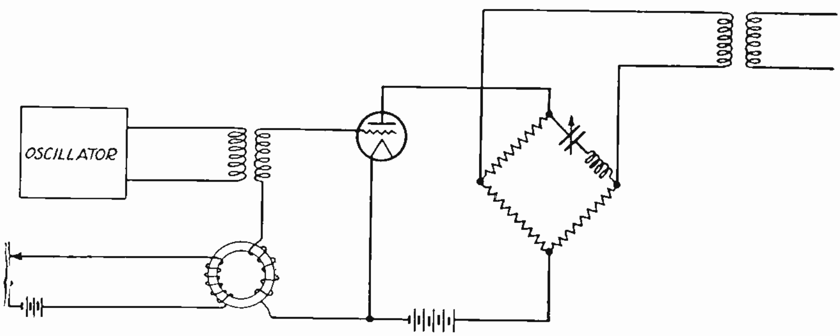

Fig. 4—Bridge Circuit Carrier Eliminator

Now having become acquainted with the advantages of this wonderfully efficient system let us see how it is accomplished. The frequencies produced when a carrier-wave is modulated are the carrier-wave, the carrier plus the speech frequencies,

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and the carrier minus the speech frequencies. This is represented in Figure 3.

Fundamentally then in single side band radiotelephony it is necessary to modulate a carrier with speech, pass this modulated frequency through a filter which removes the carrier and the undesired side band, and finally pass this current to our power amplifier tubes for radiation from the antenna.

Filters are resonant circuits whereby any desired frequency or band of frequencies may be eliminated. They can be built for all audio and radio frequencies. It is much more difficult to filter low frequencies than high ones and also much costlier. In the elimination of one of the two side bands considerable difficulty is encountered due to the proximity of these bands to one another.

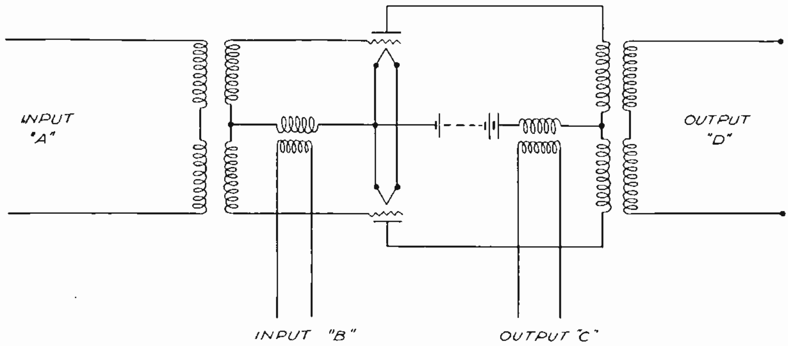

Fig. 5—Balanced Modulator

We will first consider the elimination of the carrier. Two methods in use will be described. That in Figure 4 is known as the bridge method and functions as follows: The bridge arrangement in the plate circuit of the modulator contains one arm tuned to the carrier frequency, and is balanced for it. The carrier cannot pass through this bridge network and nothing will reach the output transformer except the side band modulations that pass through the bridge which is unbalanced for any except the carrier frequencies.

The type of carrier-wave suppressor mainly in use today is that of the balanced modulator type shown in Figure 5. In this device two modulator tubes are employed wherein the carrier frequency is fed in through a parallel feed to the two grids at input B. Speech is introduced at input A and acts in opposition to the input B. The transformer marked output D

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will not deliver any of the carrier, but will merely transmit the side bands. Output coil C is used in conjunction with coil D and permits a greater flexibility in the phasing of the currents in this type of modulator.

Having now disposed of the carrier frequency it is next necessary to dispose of one of the side bands. This could be accomplished by means solely employing band filters. This

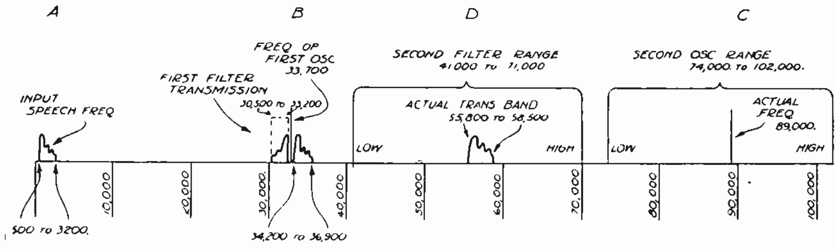

Fig. 6

is too expensive a process however, and an equally efficient and cheaper way is that of double modulation. This method permits the securing of a single side band at a frequency point that is most favorable to low priced filters and then using this output to remodulate an oscillator at a higher frequency.

This double modulation scheme of eliminating one of the side bands is really quite simple and considering it from a mathematical standpoint, is just a case of addition and sub-

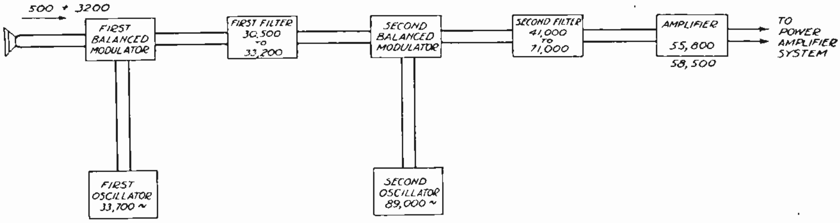

Fig. 7

traction. In order that you may understand this scheme thoroughly, let us consider a specific case, where the speech frequencies to be transmitted, lie between 500 and 3,200 cycles.

Right at this point let us recall something that has been stated before. "The frequencies produced when a carrier-wave is modulated by a speech frequency band, are the frequency

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of the carrier, the carrier plus the speech frequencies and the carrier minus the speech frequencies."

Let us consider Figures 6 and 7. The frequencies that we are interested with, at the start, are the audio-frequencies between 500 and 3,200 cycles (this is the frequency band of the speech to be transmitted). These speech frequencies are put into the first balanced modulator.

The energy from an oscillator having a frequency of 33,700 cycles is also applied to the first balanced modulator. This oscillator frequency can be termed the carrier frequency, at this point in the circuit. The resultant frequencies produced by the beating of this oscillator frequency with the speech frequencies named, are, 33,700 plus (500 to 3,200), or, 34,200 to 36,900 (the upper side band) and we also have the lower side band of 33,700 minus (500 to 3,200) or 33,200 to 30,500.

The carrier is eliminated by the balanced modulator and the first filter only passes those frequencies between 30,500 and 33,200 cycles, so only one side band passes through, the lower one, and the upper side band is eliminated.

The function of the first oscillator was to raise the side band frequencies to a point where a "not too expensive filter" could be used to remove one of the bands. You will note that this filter has to be quite sharp due to the proximity of the two bands, one of which is desired and one of which is not desired. Now, this resultant frequency band is beat with another oscillator which functions to produce two widely separated side bands, one of which can easily be filtered out, and the filtering process is complete.

So, from the output of the first filter, the frequencies between 30,500 and 33,200 are applied to the input of the second balanced modulator. The second oscillator frequency is applied at this point. The frequency of this oscillator is variable over a wide range to permit varying the wave-length of the signals emitted from the transmitter output circuit, since the wave-length in question is a function of the frequency of the second oscillator. In this specific case, the actual frequency of this oscillator is 89,000 cycles.

The resultant frequencies in the output circuit of the second balanced modulator are, 89,000 plus (30,500 to 33,200) or 119,500 to 122,200 (the upper side band) and 89,000 minus (30,500 to 33,200) or 55,800 to 58,500 (the lower side band). Here again, the carrier is eliminated by the balanced modulator, so the two side bands are passed on to the second filter, which

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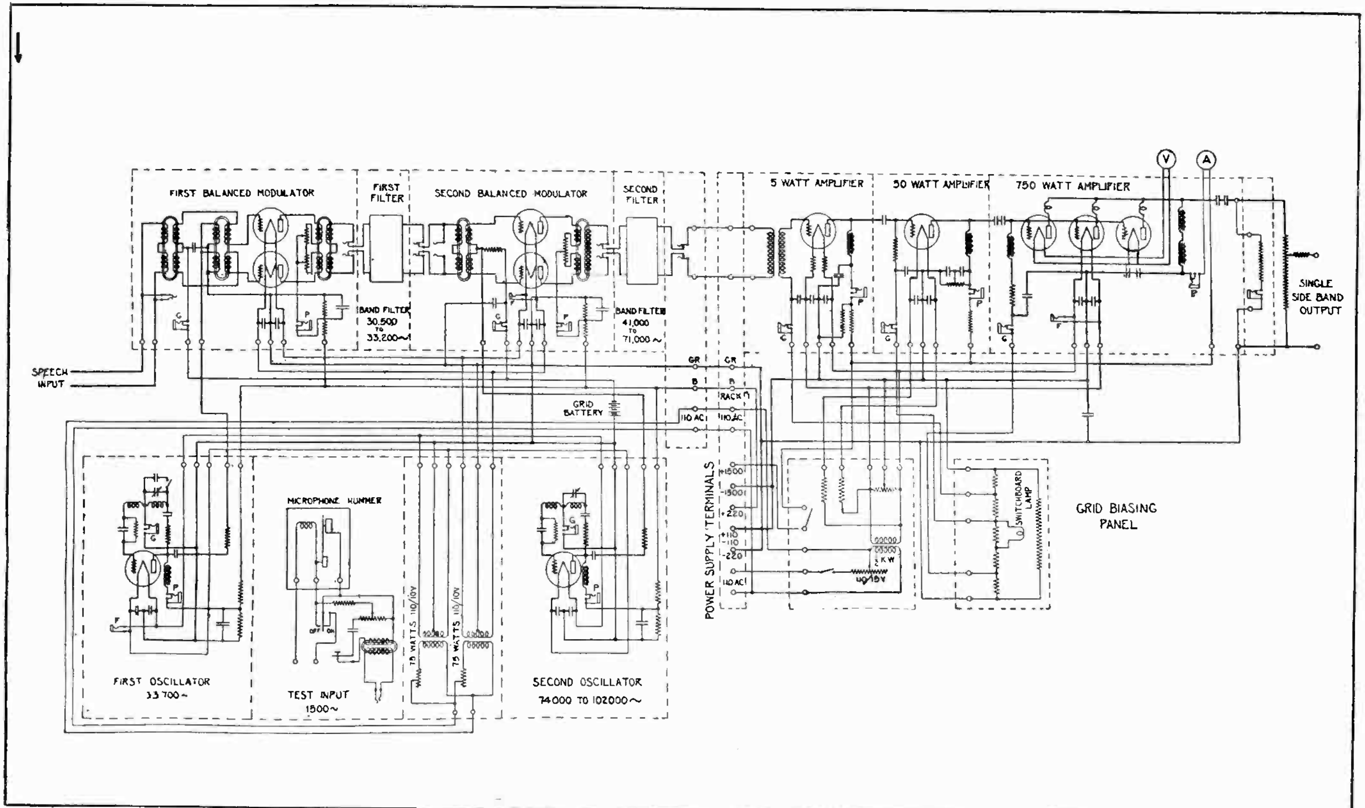

Fig. 8—Wiring Diagram of Speech Circuits.

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has, as you will note, a comparatively broad range, namely, from 41,000 to 71,000 cycles. This filter passes the lower side band very nicely but eliminates the upper side band which you will see, is way above the range of the filter.

Now we have eliminated the carrier and have completely eliminated one side band, and the one remaining side band is the one to be transmitted. We now have the 2,700 cycle band between 55,800 and 58,500, which is passed through numerous stages of amplification and is finally radiated from the antenna system. Obviously the transmitted wave-length is a variable between the two limits, 300,000,000 ÷ 58,500 and 300,000,000 ÷ 55,800 or, 5,130 and 5,370 meters, approximately and respectively.

Figure 8 shows the wiring diagram of the entire speech circuits, up to the power amplifier circuits, which will be treated next. Before leaving the modulator circuits, it might be well to make the point clear, that the second oscillator and filter circuits are variable in order that changes of wave-length may be readily accomplished, to avoid interference.

The output of the second filter system is applied to a five watt low power amplifier as represented in Figure 8. This output is a single side band and without carrier. After amplification in the five watt stage the output energizes the fifty watt stage and hence a bank of three two-hundred and fifty watt tubes. The full power of these amplifier tubes is not realized due to the desire for distortionless amplification which cannot be attained when working power tubes at their full rating.

The input to the five watt amplifier was through the usual input transformer windings, and it will be observed that the last two stages which, are purely voltage step-up stages, are choke coil amplifiers. In Figure 8 is also shown a microphonic hummer capable of producing a fifteen hundred cycle note for test purposes. This hummer is similar to the ordinary buzzer, except that instead of the usual contacts a telephone microphone is employed. This gives a purer note than a contact buzzer, and is used to show the modulating efficiency of the circuit. It is connected to the point marked speech input.

The power supply for this low power amplifier is obtained from several sources. The modulators and oscillators are energized by the two twenty direct current circuit of the station. The power amplifier plates are fed from fifteen hundred volt

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direct current generators. The filaments are all supplied by means of step-down alternating current transformers.

The modulator, filter and low power amplifier apparatus is all located in a totally copper screened room. This was necessary in order to prevent any feed back from the high power amplifier which would cause singing. The power delivered from the modulator oscillator is only one thousandth of a watt while that of the high power amplifier to the antenna is on the order of over one hundred kilowatts. The ratio of these powers is about one to one hundred million, and it is easily apparent how some of the enormous antenna current could be induced into the modulator circuits.

THE HIGH POWER AMPLIFIER CIRCUITS

Unlike radiotelegraph tube transmitters, quality radiophone transmitters must not be operated at more than two-thirds of their rated capacity if distortion is to be avoided. Our output from the low power seven hundred and fifty watt amplifier is therefore on the order of five hundred watts. This power is eventually stepped up to an output of approximately one hundred and fifty kilowatt, although the last power amplifier is capable of an output of over two hundred kilowatt for telegraphic transmission.

These immense outputs are only available by means of water cooled tubes paralleled in banks of ten. Each tube is rated at twenty kilowatts output. Tubes of this order are very expensive and when operated together must be individually protected in order that the burning out of one tube would not cause an overload to be placed on the others. Each tube has an overload relay which cuts the plate supply off should the current drawn become too great to be safely handled.

Due to the immense quantity of current that is dissipated on the plates a continuous circulation of water is necessary and each tube is fitted with a water flow alarm. In case that a stoppage should occur a contact arm in a special type of valve would close and throw the main circuit breaker thereby cutting all plate current from the set. The value of each tube is about six hundred dollars, and the safety devices are the only insurance possible for maximum life of the tubes.

Figure 9 shows the high power amplifiers, rectifiers and output antenna circuits. It will be observed that we really have three different amplifiers, low, intermediate and high power.

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The five hundred watt output of the intermediate power amplifier feeds the grids of two twenty kilowatt tubes which comprise the first stage of the high power amplifier.

This output is then connected to the grids of the last stage which consists of two banks of ten, twenty kilowatt tubes. Either bank may be operated singly or the two in parallel. This output is then loosely coupled to a multiple tuned antenna which will be described latter.

PLATE CURRENT SUPPLY

Current at a potential of ten thousand volts, and a capacity of two hundred kilowatts is necessary to energize the high power amplifier plates. Direct current generators at this voltage and current, are difficult to construct and maintain. A much easier way is to step up alternating current at a slightly higher potential than that required and then rectify by means of rectifier tubes, and filter circuits.

At the Rocky Point Radiotelephone Station the power supply is twenty-two thousand volts, three phase sixty cycles. A bank of twelve tubes each capable of an output of twenty kilowatts at ten thousand volts, rectify the alternating current, the form of which becomes the usual pulsating type. It is now necessary to smooth out this ripple, and this is accomplished by means of a filter circuit. This filter circuit is composed of series inductances and shunt capacity which opposes the varying current voltage level output of the rectifier tubes in such a manner that this ripple is reduced to practically a pure direct current.

It is necessary to supply the rectifier tubes with a voltage higher than the output potential on account of a loss in the filter circuit. This is shown in Figure 10. A is the applied alternating current. B is the rectified current of pulsating form, and C is the resultant filtered current of a practically pure direct current characteristic.

The plate current is then supplied to the first and second stage high power amplifiers through suitable protective chokes which prevents high-frequency surges. In addition, safety gaps are provided that present a ground path for any surges that should take place. Relays are also provided which automatically shut off the main power supply. The filter condenser consists of some twenty-five hundred paper telephone condensers in a

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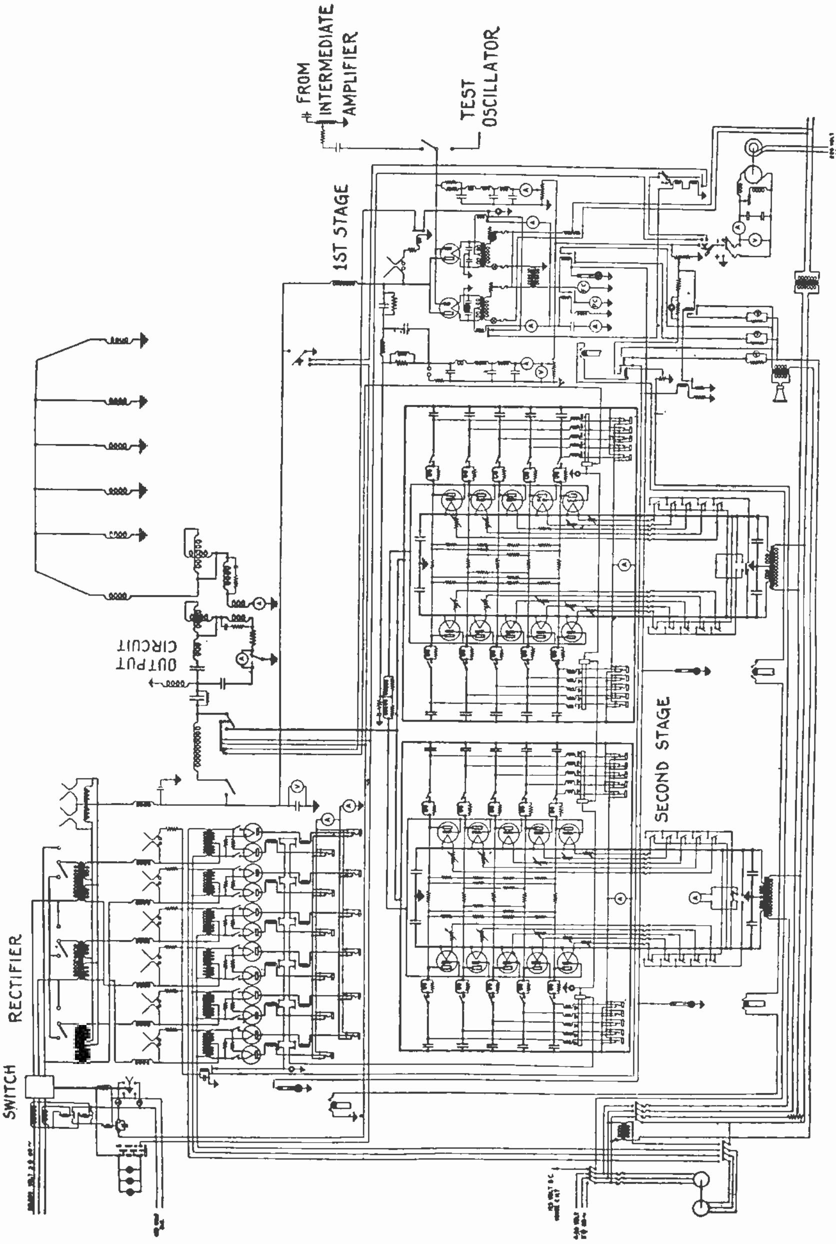

Fig. 9—High Power Amplifiers, Rectifiers and Output Antenna Circuits.

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series-parallel arrangement giving a capacity of three microfarads and a potential safety of seventeen thousand volts.

OUTPUT AND ANTENNA CIRCUITS

We have followed our input from the intermediate circuit to the modulating of the grids of the first stage of the high power amplifier and from there the output is used to modulate the twin banks of ten high power tubes. It must be remembered that we are also controlling the frequency of the transmitter simultaneously by means of oscillators. In coupling to the antenna we are primarily interested in efficiently coupling our

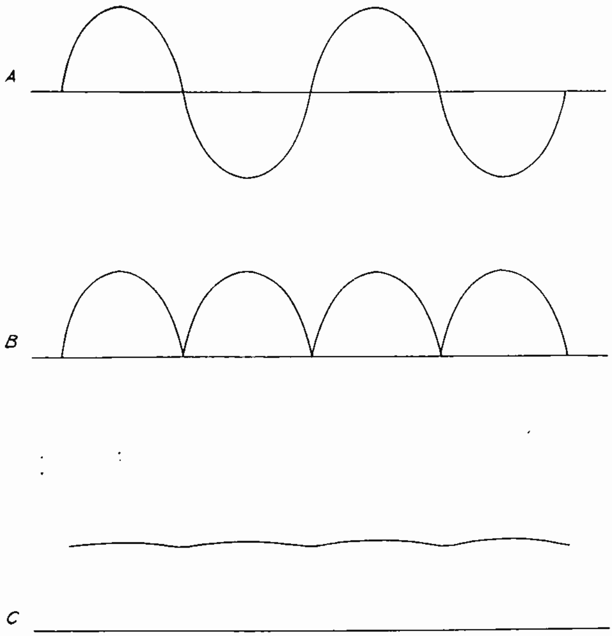

Fig. 10

amplifier system to the multiple tuned antenna. In other words, we must match the impedances of the power tubes and the antenna load in order that the transfer of energy is at its greatest value.

In order to do this we find it necessary to construct an intermediate circuit because of the wide difference between the characteristics of the power tubes and the antenna circuits. By means of this intermediate circuit we satisfy the requirements of both circuits and have an efficient transfer of current

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from the closed to open circuits. It is also necessary in this tank or intermediate circuit that all frequencies be passed with equal intensities otherwise distortion can take place.

Let us first consider the antenna we find in use. This is the multiple tuned type as invented by E. F. W. Alexanderson. This is shown schematically in Figure 11 and consists of ground connection, current meter coupling inductances, antenna proper, and the requisite number of down leads with their attendant inductances tuned to the desired frequency. This type of antenna has several advantages over the usual antenna methods. Primarily the chief advantage lies in a very low resistance and a correspondingly high antenna current. Another feature is that the arrangement is practically a filter circuit and suppresses harmonic currents. At the frequency used (57,000) the resistance is less than one ohm.

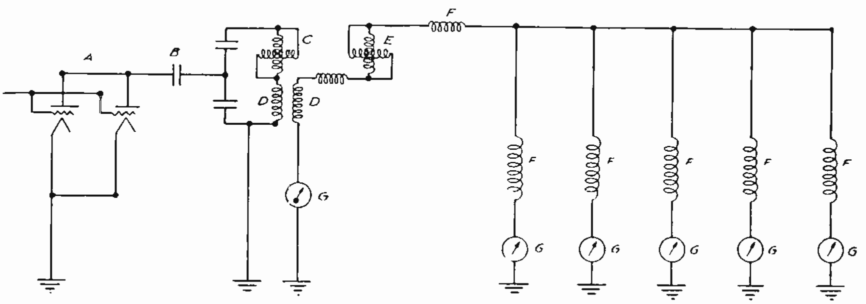

Fig. 11

Our tank or intermediate circuit consists of capacity, inductance and resistance and is tuned by means of one of the inductances being in variometer form which permits a variable control over the impedance of this circuit. Having a fairly high plate impedance, and a low antenna impedance it is the duty of this circuit to couple these two circuits efficiently. This tank circuit may be said to be comparable to an ordinary audio-frequency amplifier in that our plate impedance is matched by the primary and the grid impedance by the secondary.

This output circuit is shown schematically in Figure 11 where the output of the tubes is shown at A. B is a capacity branch which provides a low impedance path for harmonics, D being the inductances coupling antenna and tank circuit tuned by the variometers C and E. The F's are the antenna tuning inductances and are tuned for the proper input feed

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ratios. The G's are the radiation meters and all down leads must be added in order to secure the total current flow in the antenna.

It will be seen from this text that high power radiophone equipment differs radically in equipment and operation from that of low power stations. It will be well for the radio engineer desiring work of this nature to be well grounded in power plant equipment, and especially that branch that involves the use of multi-phase transformers.

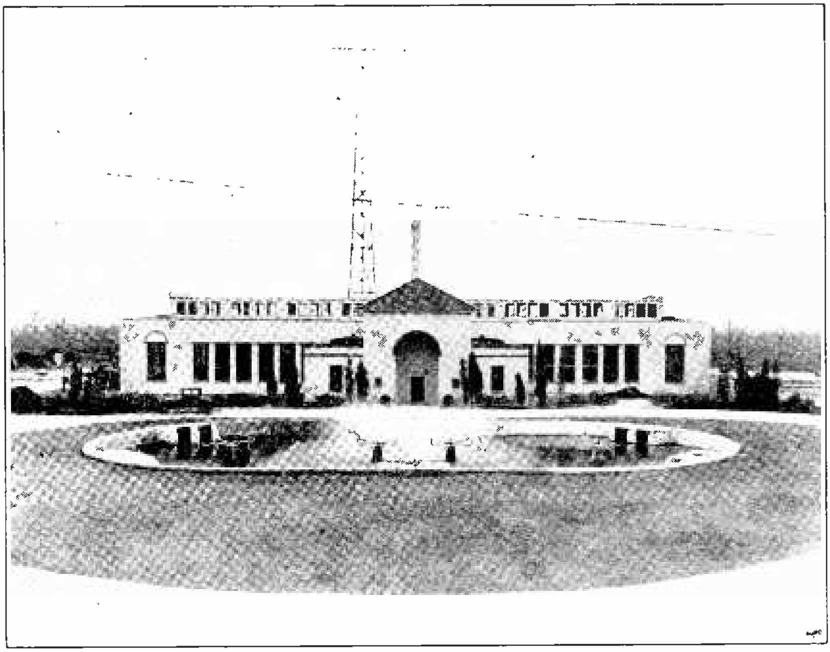

Fig. 12—Rocky Point Transmitting Station

There is considerable auxiliary apparatus in addition to that enumerated, and consists of testing oscillators, oscillographs for the proper adjustment of modulating currents, the usual power measuring equipment, electrical recording clocks for measuring the time the equipment is in operation and a multitude of safety devices for the protection of the equipment.

Long wave stations must also be protected against the carrying away of the antenna due to the weight of sleet. Special low voltage high current transformers are provided which are capable of actually raising the temperature of the antenna wires to a point where the ice will melt.

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The trans-Atlantic Radiotelephone Station just described, is located at Rocky Point, Long Island, and is operated by the American Telephone and Telegraph Company in conjunction with the Western Electric Company.

Figure 12 is an exterior view of the Rocky Point Station which houses the single side band eliminated carrier radiotelephone transmitter described. You can see one of the 500 foot towers in the background that support the transmitting antenna.

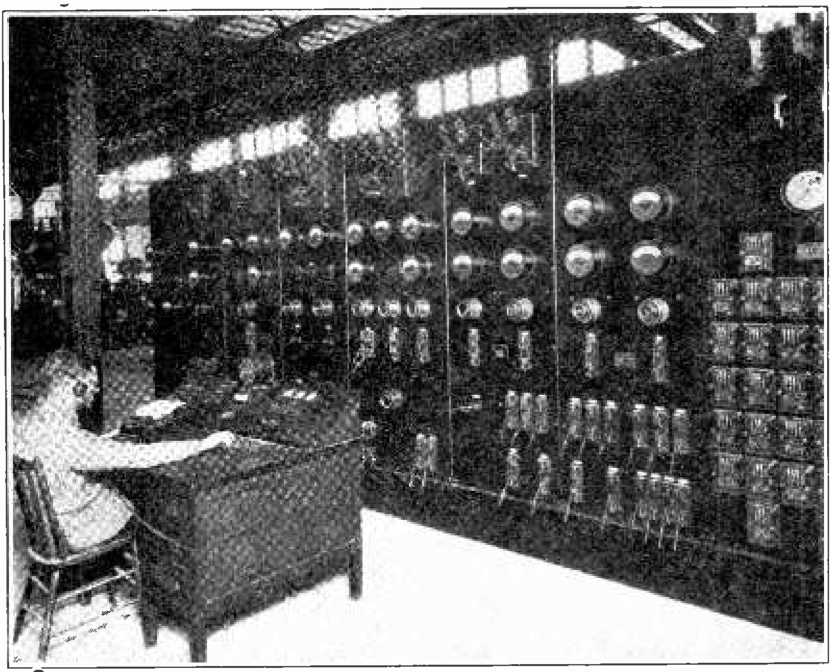

Fig. 13—Main Control Panel, Rocky Point Single Side Band Eliminator Carrier Transmitter

Figure 13 is a view of the main control panel. The station operator's desk is shown in the foreground. Figure 14 is a view of one bank of twenty kilowatt tubes.

Figure 15 shows one of the enormous outdoor tuning coils used for tuning the antenna, in a multi-tuned antenna system. The power house is shown in the background and you can see the lead from the power house, to the first tuning coil, which carries the radio-frequency output energy to be radiated from the antenna system.

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SINGLE SIDE BAND ELIMINATED CARRIER RECEIVER

Although it is true that fairly intelligible speech may be picked up on an ordinary type of receiving set, from the particular type of transmitter that we are discussing in this section, it is also true, that to produce anything like commercial quality, it is necessary to have a special type of receiver.

Figure 16 is a schematic layout of a receiver used in picking up signals transmitted from a single side band eliminated carrier transmitter. As you will see from the diagram, recep-

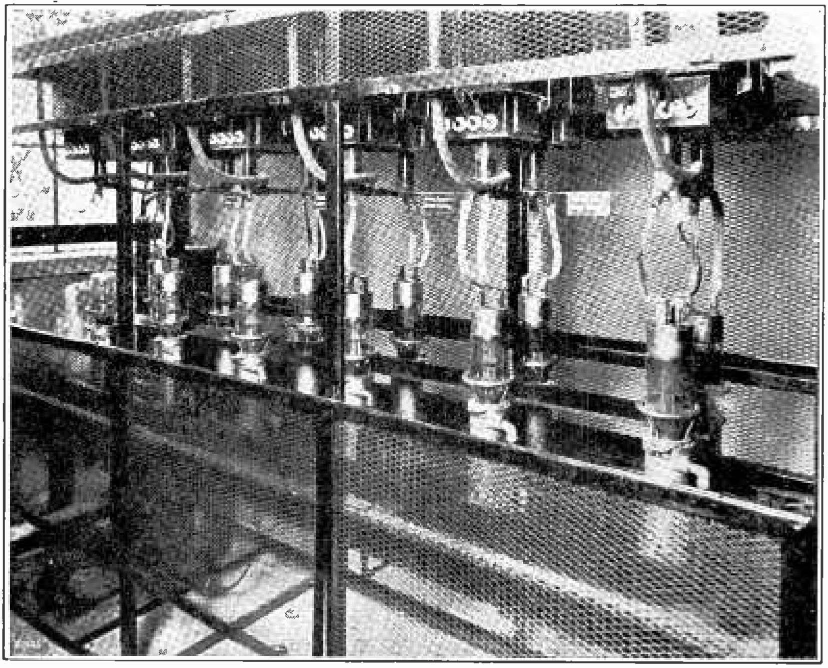

Fig. 14—20 K. W. Tubes in Rocky Point Single Side Band Transmitter.

tion is carried out in two steps. The received side band is passed into the high-frequency detector circuit where it is combined with energy from a local oscillator having a frequency of 89,000 cycles.

The resultant frequencies are, 89,000 cycles, 89,000 plus (55,800 to 58,500) or, 144,800 to 147,500 and 89,000 minus 55,800 to 58,500) or, 30,500 to 33,200 cycles. This energy passes through a filter having a range of from 30,500 to 33,200 cycles, thus eliminating the carrier and the upper side band and the lower side band is passed through to the intermediate

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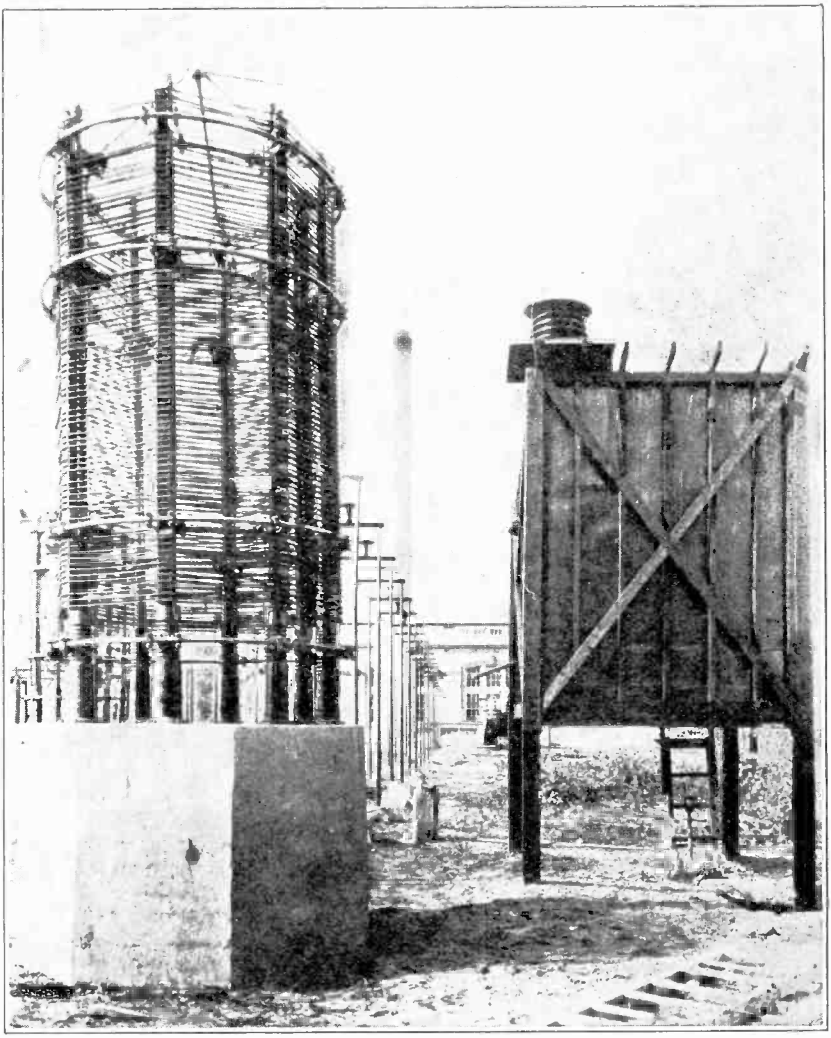

Fig. 15—Outdoor Tuning Coil for Rocky Point Single Side Band Transmitter

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frequency amplifier and thence to the low-frequency detector where it is beat with another oscillator having a frequency of 33,700 cycles.

The resultant frequencies in the detector circuit are 33,700, 33,700 plus (30,500 to 33,200) or, 64,200 to 66,900 and 33,700 minus (30,500 to 33,200) or, 3,200 to 500 cycles. In this part of the circuit, it is only with the different frequency band that we are concerned, it being audible and the carrier as well as the upper side band being of too high a frequency to be audible to the human ear. So you will see that we have arrived back at a point where we have exactly the same speech frequency band as we started with, namely, 500 to 3,200 cycles.

COMMERCIAL TRANS-ATLANTIC TELEPHONY

The American Telephone and Telegraph Company have installed a 200 kilowatt telephone transmitting station, of the type described in this section, at Rocky Point, Long Island, and there is no question that all of their tests will culminate in the inception of commercial trans-Atlantic radiotelephony.

During 1925, the company in question spent a considerable amount of time and money in the development of the transmitting and receiving equipment, explained, in general, in this section. The first part of 1926, found the status of the situation such, that, "finis" was written to the major part of the development, and it was decided, to hold a demonstration, before members of the press, showing them, so they could tell the world at large, the feasibility of trans-Atlantic Radiotelephone Communication.

On March 7, 1926, Sunday, two-way radiotelephonic communication was carried on between people in New York City and people in London, England. Numerous separate conversations were carried on, the total time involved for all the conversations being four hours. This, together with the fact that on Sunday after Sunday, tests have been carried on between New York and London, the two points being in constant telephone touch with each other for eight hours at a stretch, gives you an idea of the consistency of this trans-Atlantic radiotelephone service.

During the two-way communication tests, it is necessary to have a transmitter and a receiver at each end of the circuit. For instance, on the American end of the circuit, the receiver is located at Houlton, Maine, and the transmitter at Rocky Point,

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Long Island. The person talking to London may be located anywhere in the United States, but let us assume that he is talking from New York City.

The speech from the gentlemen located in New York is sent over land lines to the Rocky Point transmitter where it is subsequently "put on the air." This radio-frequency energy is picked up on the English side of the circuit and is applied to the ear-phones of the Englishman who is talking from London.

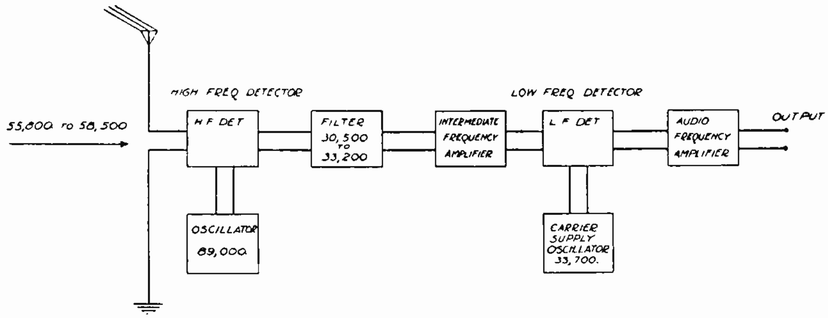

Fig. 16

The speech from this last named gentleman goes out over the land lines to the transmitting station over there, and thence by radio to the receiving station at Houlton, Maine, where it is picked up and sent over the land lines, in the form of speech frequency currents, to the ear-phones of the gentleman talking from New York. That completes the circuit.

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RADIO RELAY STATIONS

A radio relay station is one that picks up radio signals and relays them, by radio, to more remote points. A relay station in a radio circuit is analogous to a repeater station in a telephone circuit.

In this section we are going to consider the methods involved in the relaying of transatlantic broadcasting signals; the relaying of transatlantic telegraph signals; the relaying of transcontinental radio picture signals and the relaying of the Arlington time signals.

RE-BROADCASTING EUROPEAN BROADCAST PROGRAMS IN THE UNITED STATES

A most elaborate re-broadcasting test was successfully carried out on January 1, 1926, when a program of music from the Club Ciro in London, England, was re-broadcast by a chain of radio stations throughout the United States. This test was conducted by the Radio Corporation of America and convincingly showed the possibility of American radio fans "listening in" on European broadcast programs, but it also showed the necessity of a radio relay station to make this possible.

There are a vast number of people in the United States who derive a great deal of pleasure from "listening in" on broadcast programs from the other side of the Atlantic. There are very few of these folks who are able to pick up European broadcast signals, direct, (on their own receivers), for two main reasons. The first is, that in the majority of cases, their radio receivers are not sufficiently sensitive and the second reason is, that their geographical location is not sufficiently favorable to transatlantic reception.

In order to receive transatlantic broadcast signals here in the United States, direct from Europe, with any degree of consistency it is necessary to have a supersensitive receiver and to be located at a point conducive to good reception from Europe.

Now it isn't everyone that is in the proper location, and, of those that are, there are few that can afford to invest in the type of receiver necessary.

It devolved upon the Radio Corporation of America to utilize the facilities at their command to attempt to supply the American radio fan with broadcast programs from Europe.

Intensity tests were made all along the eastern coast of the United States in the search for the ideal location. From

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a summary of the quantitative data thus obtained, they found that the territory around Belfast, Maine, is particularly free from static disturbances and the intensity of radio signals from Europe is, also, particularly good.

They built a radio receiving station at Belfast, Maine, and equipped it with the most sensitive receiving apparatus available.

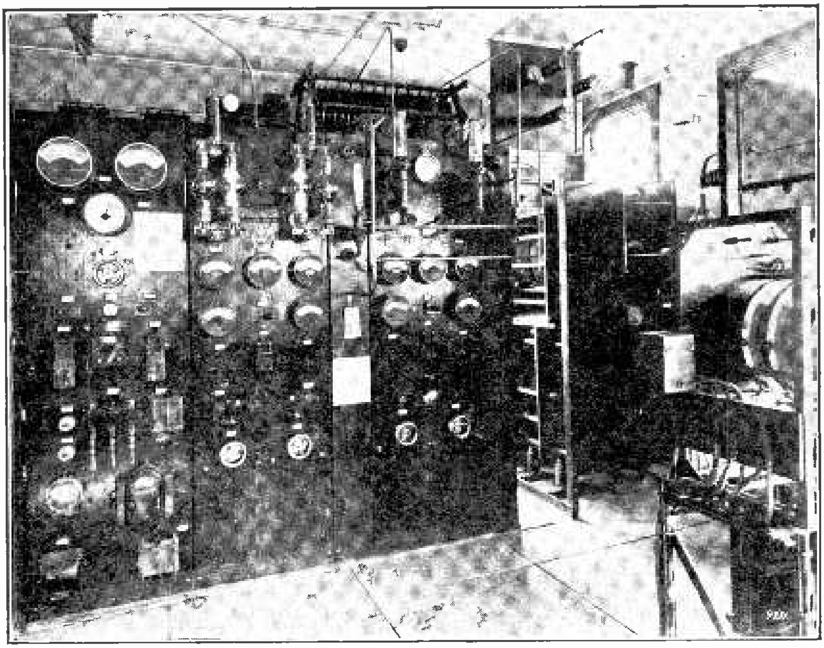

Fig. 17—Interior View of Station, Belfast, Maine.

A "wave antenna" is used for picking up the signals. This antenna consists of two wires elevated from the ground about twenty feet by telegraph poles, the length of the antenna being a function of the wave-length of the signals that it is desired to receive. This antenna is made approximately one wave-length long for best results, hence in the case of 1,560 meter signals, the antenna is about 1,560 meters long or, in other words, about a mile long.

The "wave antenna" is unidirectional, in that one of its inherent characteristics is to receive signals best from one direction, and to receive practically nothing from all other directions. Obviously, this characteristic tends towards a reduc-

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tion in static—signal ratio. When a "wave antenna" is designed to receive from one particular direction it has the effect of receiving an amount of energy from that particular direction, equivalent to the amount that would be picked up by an ordinary receiving antenna, 1,000 feet high.

This combination of ideal location and sensitive receiving equipment resulted in the consistently satisfactory reception of European broadcast signals, and with these signals available at Belfast, the next thing to consider was the problem of getting them to the different broadcasting stations to be put on the air.

In view of the fact that high grade telephone circuits were not available for the use of the R. C. A. between Belfast and New York, at the time the receiving station was built, it was necessary to build a transmitting station for relaying the signals on to more remote points in the United States where conditions were not conducive to consistent reception for Europe.

A transmitting station was built at a point about three miles from the receiving station. This transmitting station was equipped with transmitters, designed to operate on various wavelengths. The transmitter that we wish to consider at this time is the one that was designed to operate on 70 meters. We will just consider this transmitter in general, because it is the one that was used to relay the European broadcast signals from Belfast to New York.

Figure 17 is interior view of the transmitting station.

Figure 18 is a schematic diagram which gives you a general idea of the circuit arrangement at the relay station and shows the method of producing and modulating the "carrier."

A crystal oscillator is used to insure constant frequency. The energy from the crystal oscillator circuit is applied to the grid of the 5 watt tube (T_1). The output circuit of this tube is inductively coupled to the input circuit of another 5 watt tube (T_2). The output circuit of (T_2) is coupled to the input circuit of a push-pull amplifier consisting of the two 5 watt tubes (T_3) and (T_4).

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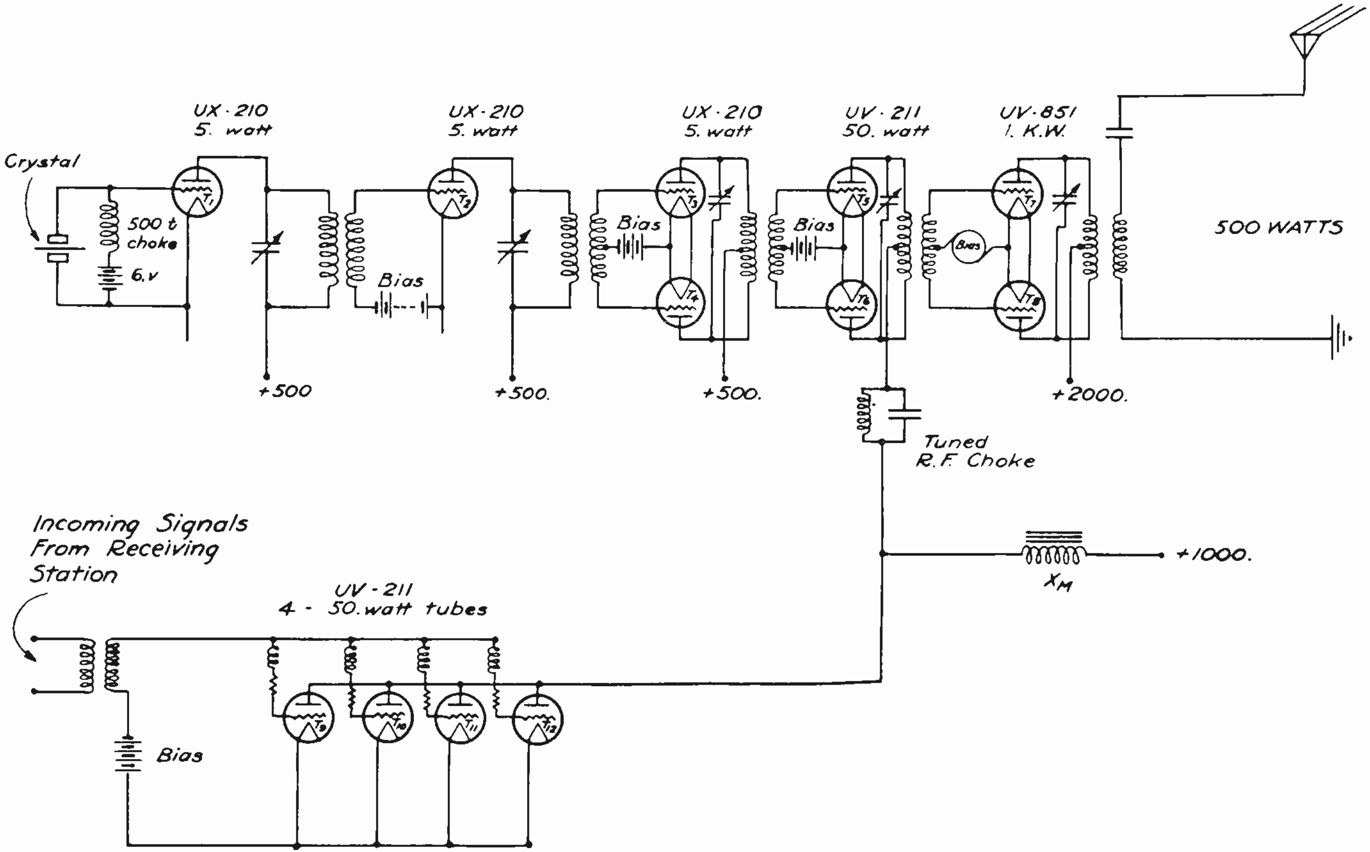

Fig. 18

SCHEMATIC WIRING DIAGRAM OF BELFAST 70 METER RADIO RELAY TRANSMITTER

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The output circuit of the 5 watt push-pull amplifier is coupled to the input circuit of another push-pull amplifier consisting of the two 50 watt tubes (T_5) and (T_6). Modulation is effected in this stage and we will come back to that shortly.

The modulated radio-frequency energy in the output circuit of the 50 watt push-pull amplifier stage is applied to the grids of the two 1. kilowatt tubes (T_7) and (T_8) which, with their associate circuits, form another push-pull stage of amplification. This last stage of amplification must be linear, obviously, or distortion will occur. The output circuit of this last stage of amplification is coupled to the antenna.

Now let us go back a bit and consider what happens to the European signals when they are produced in the output circuit of the apparatus at the receiving station. This energy, in audio-frequency form, is "piped" over to the transmitting station on a pair of wires. At the transmitting station it is applied to the grids of four 50 watt amplifier tubes, (T_9), (T_{10}), (T_{11}) and (T_{12}), these tubes being connected in parallel.

The plates of these tubes are supplied from a 1,000 volt D. C. source of energy through the iron-core choke coil (X_m) and you will note that the plates of the two oscillator tubes (T_5) and (T_6) in the 50 watt push-pull amplifier stage, are also supplied from the same source and through the same choke coil (X_m).

The presence of this choke coil in the common plate supply to the two oscillators mentioned and the four modulator tubes, functions to maintain a constant supply of plate current. This means that when the grids of the modulator tubes go positive due to signal voltage being applied to their grids, the current flow to the modulator plates increases and since the choke coil (X_m) tends to maintain a constant supply of plate current to the six tubes involved, the increase in plate current flow to the modulator tubes will result in a corresponding decrease in plate current flow to the oscillator tubes.

It is in this manner that modulation is effected and the peak current values of the radio-frequency pulsations in the output circuit of the 50 watt push-pull amplifier tubes will rise and fall in synchronism with the audio-frequency variations in the voltage applied to the grids of the four modulator tubes due to the European broadcast signals as they are supplied from the output of the audio-frequency power amplifier at the receiving station.

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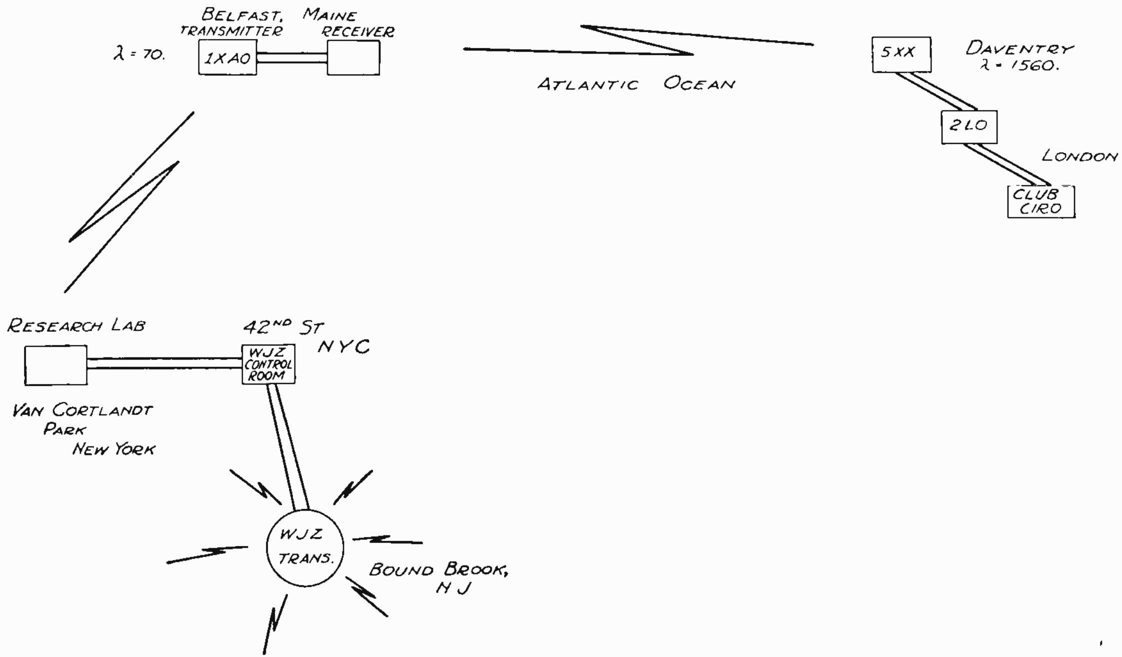

Fig. 19—This Shows the General Schematic Layout for Relaying Broadcast Programs.

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Thus the signals from Europe, picked up at Belfast on 1,560 meters, are made to modulate the 70 meter radio relay transmitter and they are again put on the air, but this time, on a wave-length of 70 meters. These signals are picked up at the research laboratory of the R. C. A. located in Van Cortlandt Park, New York City. They are tuned in on a short wave receiver, detected, amplified and put on a direct pair of wires to the control room of WJZ, in the Aeolian Building, on 42nd Street in New York City.

In any event, signals that come into the control room are "piped" out to the transmitting station of WJZ, which is located at Bound Brook, New Jersey.

Now we come to a summary of this whole situation. A great many folks throughout the land know that it is possible to pick up signals from Europe here in the United States and they know that European broadcast programs have been received here and re-broadcasted from local stations, but there are comparatively few who know of the exact circuit arrangements involved. Figure 19 shows the general schematic layout.

As has been said before, the first really successful attempt at re-broadcasting European broadcast programs in the United States, took place on January 1, 1926, (Figure 19 shows the circuit arrangement involved in the tests in question).

A program of music from the Club Ciro in London was rebroadcast in the States for a period of half an hour. This music, originating in the Club Ciro, was transformed into electrical pulsations of audio-frequency by means of the microphone and its associate circuits. These audio-frequency currents were piped over to the control room of broadcasting station "2LO", in London, on a pair of telephone lines.

At the control room of station "2LO", these audio-frequency currents were diverted into two separate channels. One led to the modulator tubes of the British station in question and the other, to the experimental transmitting station at Daventry, England. In the former case, the signals were broadcast over station "2LO" on 360 meters, for reception by British radio fans and in the latter case they were sent out from "5XX" on 1,560 meters, for reception by American fans, although in this latter case the signals were not, in general, received directly, by the fans, but only after the interplacement of a radio relay station. Since it is with radio relay stations that we are con-

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cerned in this section, we will follow the path of the signals on their journey from the source in London to the points where they were put on the air for reception by American radio fans.

The audio-frequency signals arriving at Daventry, England, were amplified and applied to the grids of modulator tubes which in turn function to modulate the radio-frequency output of station "5XX". Hence, the sound waves, produced by the playing of the musical instruments in the London Club and which were transformed into electrical pulsations of audio-frequency by the microphone and its associate circuits at the Club Ciro, underwent another transformation at Daventry. where they were sent out into the ether in the form of modulated radio-frequency electro-magnetic energy.

These signals were picked up at the relay station at Belfast. Maine, on 1,560 meters. They were amplified, detected (hence changed into audio-frequency energy), amplified at audio-frequency and "piped" over to the Belfast radio relay transmitting station "1XAO." Here the signals were applied to the grids of the modulator tubes of the "1XAO" transmitter, the modulator tubes functioning to modulate the radio-frequency energy generated and subsequently radiated.

So, here again, the music originating in the London Night Club were "put on the air," but this time on a wave-length of 70 meters. These 70 meter signals were picked up at the Research Laboratory of the R. C. A., at Van Cortlandt Park, in New York City. They were amplified, detected, amplified at audio-frequency and put on the pair of telephone wires connecting the research laboratory with the control room of WJZ at the Aeolian Hall Building, on 42nd Street, in New York City.

In the control room at WJZ the musical program from London was passed through audio-frequency amplifiers and distributed by high grade telephone wires to the various broadcasting stations throughout the United States that were linked up for simultaneous re-broadcasting. These signals were also sent out over the control line to the Bound Brook transmitting station of WJZ where the program was "put on the air" on a wave-length of 455 meters and subsequently received by those "listeners-in," within range of this station.

That tells the story of the important part that the radio relay station plays, in the re-broadcasting of European broadcast signals. The reason for having the relay station is obvious.

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It would be possible to have the same receiving equipment used at Belfast, installed in the Van Cortlandt Park Laboratory, but the possibility of receiving European broadcast signals with any degree of consistency would be much less than the possibility of consistent reception at Belfast. Another thought to consider here, is, that the antenna used at the receiving station, for best results in receiving 1,560 meter signals, should be of the "wave antenna" type and its length should be approximately one mile. This is far more feasible at a point way off in the country than it is at a point in or near a big city like New York City.

The reason, then for using a radio relay station for making possible the re-broadcasting of European broadcast signals, is the fact that sensitive receiving equipment installed at the various broadcasting studios would not be sufficient to pick up broadcast signals direct from across the Atlantic. But sensitive receiving equipment installed in an ideal location for trans-atlantic reception, is sufficient for European broadcast reception and these signals can then be relayed with sufficient power to carry them through to the points desired.

In concluding, let us consider the rated output values for the stations mentioned in connection with the foregoing discussion.

Station	Wave-Length	Power
2LO	360 meters	1.5 K.W.
5XX	1,560 meters	25. K.W.
1XAO	70 meters	½ K.W.
WJZ	455 meters	1. K.W. minimum
		50. K.W. maximum

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TEST QUESTIONS

Number Your Answers 40 and add Your **Student Number**

Never hold up one set of lesson answers until you have another set ready to send in. Send each lesson in by itself before you start on the next lesson.

In that way we will be able to work together much more closely, you'll get more out of your course, and better lesson service.

1. Is continuous operation necessary in Commercial Telephone Stations?

2. What frequencies are used for good speech transmission?

3. Why are filters used in transmitting circuits?

4. Draw a diagram of a balanced modulator used for carrier elimination.

5. What precautions must be taken in the installation of the modulator, filter and low power amplifier?

6. State the capacity at which a radiophone transmitter should be operated to avoid distortion.

7. How are expensive power tubes protected from being burnt out?

8. What is a radio relay station?

9. Why was Belfast, Maine selected as the location for a relay station?

10. Show by a diagram how the different stations are connected for re-broadcasting European programs in U. S. What wave-lengths are used?

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