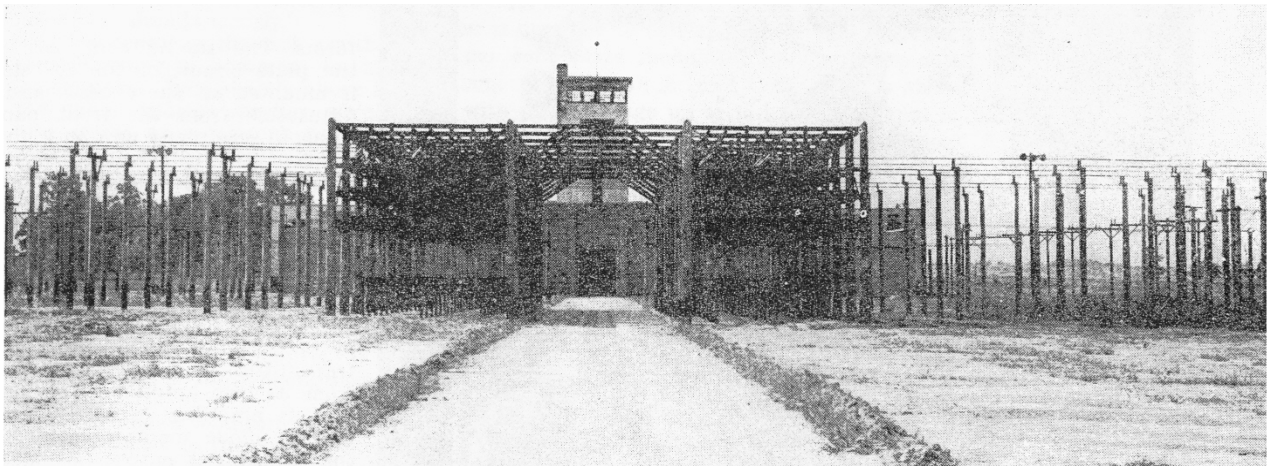

A view of the main antenna switching station with the transmission lines leading to the antennas.

OWI 200-KW TRANSMITTERS AT BETHANY, OHIO

by R. J. ROCKWELL
Director of Broadcast Engineering
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ON September 23, 1944, the Office of War Information, the Office of the Coordinator of Inter-American Affairs and the Crosley Corporation officially dedicated three new 200·kw transmitters at Bethany, Ohio. This was the culmination of almost two years of planning, designing and building, of invention and adventure in the field of radio engineering. This was the end of a trail that started with an urgent war necessity, and the beginning!: of another trail that leads forward to a new kind of *air supremacy* for the United States of America. This was *the loudest voice in the world* trying its young lungs.

On that fateful December Sunday in 1941, when bombs rained down on Pearl Harbor, Uncle Sam was internationally inarticulate, as compared with the enemy. Six international licensees were operating only 13 short-wave stations, several of which were incapable even of 5O-kW output. In contrast to this, Germany had at least 68 short-wave transmitters under her control, and it was reported that from 12 to 20 additional units of 200-kW output might be in operation by December, 1942. Japan controlled 42 known transmitters, ranging up to 50 kW. Thus, the Axis was able to carry the same program on as many as 20 different frequencies. In fact, Germany's regular service to the Americas was then using 16 frequencies.

By the most conservative estimates, we needed at least 36 international transmitters, operating on a total of· 70 frequencies between 6 and 20 mc, with powers ranging up to 200 kw, if possible. But that was a big *IF!* For, at that time. no vacuum tubes, output circuits or antennas which were capable of such powers were known to exist.

In a drastic effort to remedy the situation, the Board of War Communications called a *council of war* in Washington. All interested. parties were invited - international licensees, equipment manufacturers, representatives of the Federal Communications Commission, Office of War Information, Office of Coordinator of Inter-American Affairs, the Department of State, and others---to determine how soon existing facilities could be augmented and new facilities added. and what powers could be attained. As a result of this and subsequent meetings, it was decided that, within one year, a total of 32 transmitters could be in operation and at the disposal of OWI and CIAA. It was felt that installations could be greatly expedited by duplicating existing maximum power output, which was 100 kw, and required operation of tubes in parallel to achieve even this power.

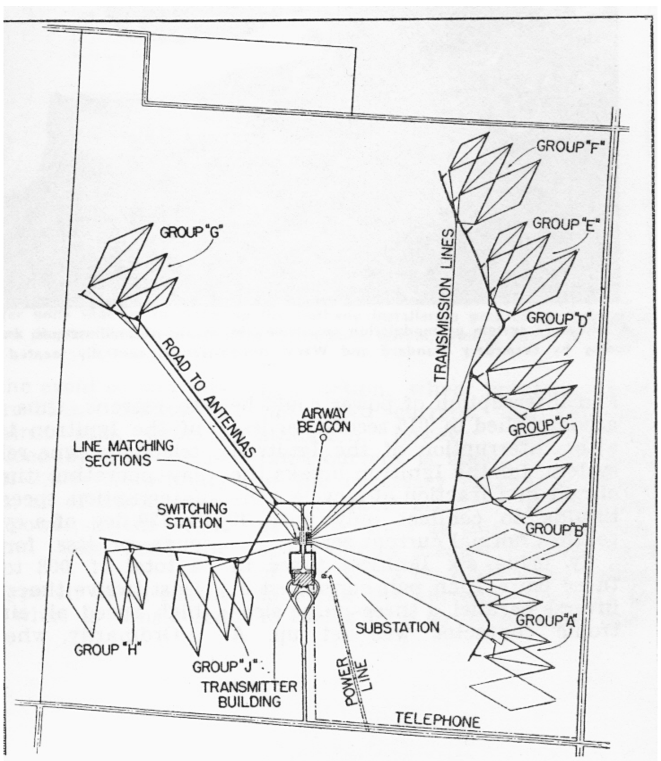


Figure 1. A general layout of the property where the 200 kW transmitters are located, with building, substation, switching station and antenna system.

But, to be on a parity with the Axis, and to be able to override interference and cope with inferior receiving conditions in foreign countries, we had to do more than just duplicate existing powers; we had to *exceed* them, we had to *double* our *greatest* previous powers!

As a part of this mammoth program, the Crosley Corporation undertook to redesign its equipment, for an output of 200 kW. Tubes were designed and developed, circuits were calculated, and antennae were devised to do the job. This paper will describe the installation in some detail, and tell of its operation.

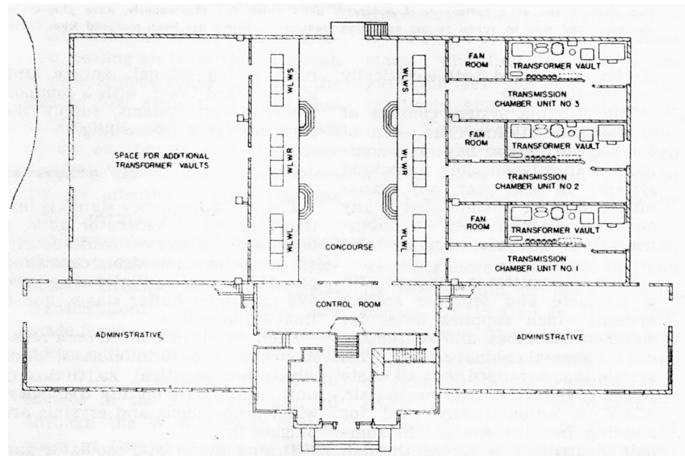


Figure 2. Floor plan of the transmitter building, showing the fireproof vaults where the high voltage transformers, filter reactors, filter condensers and high voltage control components are placed.

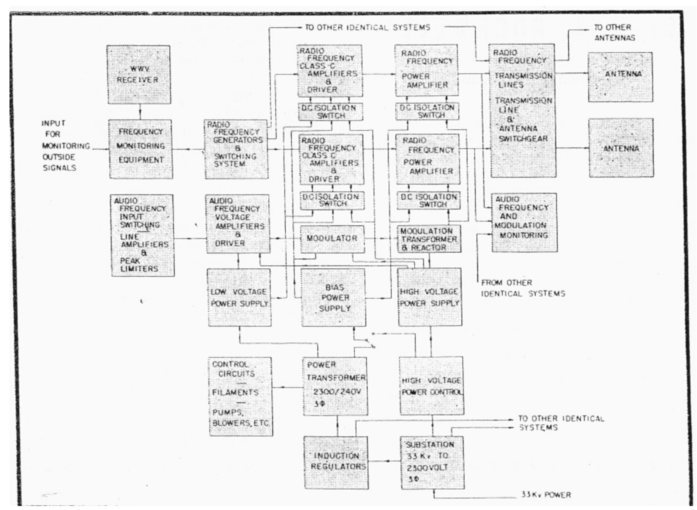


Figure 3. Block diagram of the complete transmission system.

High Power Pioneering

The story of Bethany really goes back far beyond Pearl Harbor. In the very early days of high-power, high-frequency broadcasting, when 10-kW was the power maximum, Crosley's W8XAL was a pioneering leader. Always experimenting with higher powers, its staff had already built a 50-kW transmitter when the FCC made that output a license requirement. Through continuation of these experiments, tubes were developed. capable of 75 kW, and in 1940, another momentous dedication was held, of the most powerful shortwave station in this country at that time, WLWO.

Even in the standard band, Crosley had pioneered in high power. Its world famous W8XO, on the WLW frequency of 700 kc, had operated successfully for several years prior to the war with 500 kW power. And even today, the unmodulated signal of W8XAL serves the U. S. Bureau of Standards, providing a variety of Information on radio skywave transmission, notably on absorption and its variation. From measurements of this type, the Bureau supplies OWI with advance information which enables them to schedule optimum usable frequencies for all American international stations for various times of day, season and solar cycle.

Because of these qualifications, as well as the fact that Crosley's offer to construct the three 200-kW transmitters did not conflict with urgent military orders, this responsibility was placed in the hands of the Crosley Corporation by OWI. Moreover, since at the time the decision was made. it was still considered a possibility that bombings of the East coast might be attempted by Germany, a middle-west location was desirable for security reasons.

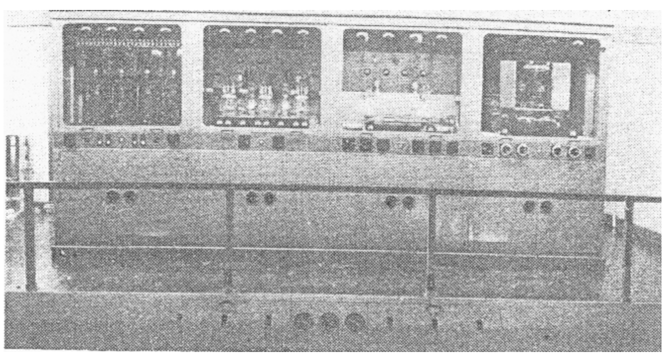


Figure 4. View of a section of the transmitter. Unit third from left is the RF driver which operates at carrier frequency throughout: range is 6-22 mc.

Once the basic plan was evolved, the first big problem was the selection of a site on which to build the project. The specifications were extremely exacting. About a section of land was required for the building, switching station and 24 rhombic antennae. And it was necessary to leave some space for future expansion without overcrowding. The ground had to be as high, or higher. than surrounding territory, and relatively level throughout and for some distance beyond. A uniform slope under and ahead of the antennas in the direction of transmission was needed, in order to lower the angle of maximum radiation of. the high frequency, directional radiators. The land had to be virtually free of wooded or populated areas for a considerable distance. A source of 3000·kva primary power was required, as well as provision of broadcast type telephone circuits, leading from the master control room ·of WLW in Cincinnati.

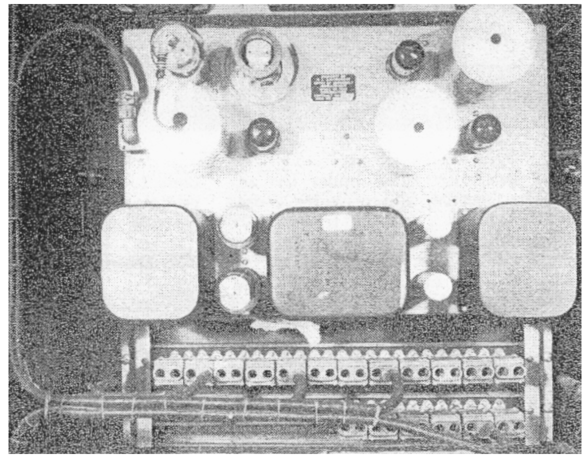


Figure 5. Rear view of one of one of the RF generators. Shield has been romeved from second buffer stage coil to show construction.

The Bethany site was chosen only after thorough studies had been made of U. S. topographical. maps covering a radius of about 50 miles around Cincinnati, and after every other possible site had been investigated. It is slightly less than.a full section of· high, relatively flat land. gently sloping generally in all directions from center, and the surrounding land is also flat and slopes slightly in favorable directions. The area is remarkably free of housing; and the few slightly wooded areas could easily be avoided in layout.

The same dual-power circuit feeding the WLW. WLWO and WLWK transmitters near Mason, Ohio, passes along the southern boundary of the property, and the telephone cables for those stations run along the eastern boundary. Thus expense, and use of critical materials, could be held at a minimum, in obtaining these vital services.· Two rail lines are within a· few miles of the place, and a good. hard surface road runs past the south entrance to the property, while satisfactory all-weather roads skirt the east and north boundaries. This was of considerable importance, due to the physical size of some of the components of the project. such as antenna poles. transformers, etc., which had to be transported to the site.

Figure 1 shows a general layout of the property, with building, substation. switching station and antenna system indicated and identified.

Tailoring the transmitter building

The building is composed of two separate units. an administrative section and a transmitter section. Although, due to the character of the design, there is an expansion joint between these sections, the two are actually one building.

Since this paper deals primarily with the transmitters, concentration will be on the details of that section, and the administrative portion will· be dismissed with the information that it is two stories high, with a four-story central tower that serves as a guard station and revolving searchlight beacon house. Offices and living quarters for resident engineers, a machine shop and a garage occupy the two stories of the building itself. while the first three levels of the guard tower contain radio-testing equipment, a storage tank for distilled water used in tube cooling, and two 1500 gallon water storage tanks, for general building purposes.

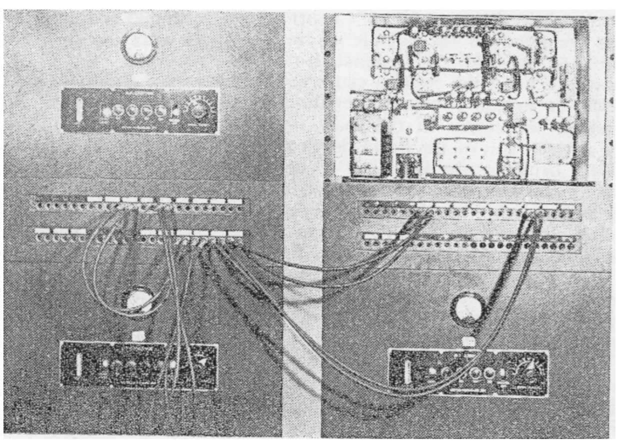


Figure 6. Partial view of the equipment bays in which the RF units are mounted. Note coaxial patching panels. RF generator front panel has been removed to reveal internal construction.

The transmitter section is entirely functional. It was designed to accommodate six transmitters with their associated equipment, and is actually six similar units, three on each side of a center concourse. This section is a monitor type building 175' wide by 75' long, with a high bay measuring 24' from floor to roof slab. Ceiling height in the side bays is 17'. This section contains some interesting features. A tunnel extends under the center of the concourse, connecting with the boiler room under the administrative section, and provides connecting facilities for the transmitters on either side, To permit the extraordinary flexibility for piping and wiring required. in this installation, a cellular steel floor was set between two mats of concrete, the upper layer being the floor of the concourse. This. steel Q-floor extends from the sides of the tunnel walls to the undersides of the transmitter catwalks.

Figure 7. Cathode ray oscilloscopes used for monitoring carrier of each transmitter. These are mounted in the control desk.

Another unusual design feature its cantilever construction. The high bay has a span of 64' between column supports. The monitor width of the high bay is 99'. To reduce the depth of the girders supporting bay beams, 17' 6?" cantilevers were designed on the outside of the columns, to support the extension of the monitor beyond the column centers. This cantilever action produced negative moments in the center of the span, permitting a reduction of the beam depth of the girders bridging the high bay. The roof slab of the side bays is suspended from the bottom level of the cantilevers, producing a design in which only three spans are necessary to bridge a total distance of 175', and which, at the same time, accomplishes the difference in ceiling heights incident to monitor-type roof construction.

The transmitter section interior consists of the center concourse flanked. by catwalks, on which are mounted six transmitter units. Directly behind these units is a continuous wall, in which is mounted, behind each individual unit, a group of cabinets which include 240-V power distribution panels, magnetic switch panels, automatic air control equipment, etc. Beyond the wall to the rear are individual fan rooms, in which are cooling fans, water pumps, and plenum chambers for distributing inlet and heated air as described later. Directly behind these fan rooms are the transformer vaults. Under the catwalks are· the filament transformers, and plumbing for distributing the water to water-cooled tubes. On the slanted front edge are water-flow meters, temperature gauges, and water controls, Figure 4.

The entire building is thoroughly grounded, a mat of wires radiating on all sides for a distance of 50', and extending to the reinforcing- bars which are welded together within the concrete. This was done to eliminate the possibility of cross-modulation, and to provide a good ground matting for the transmitters.

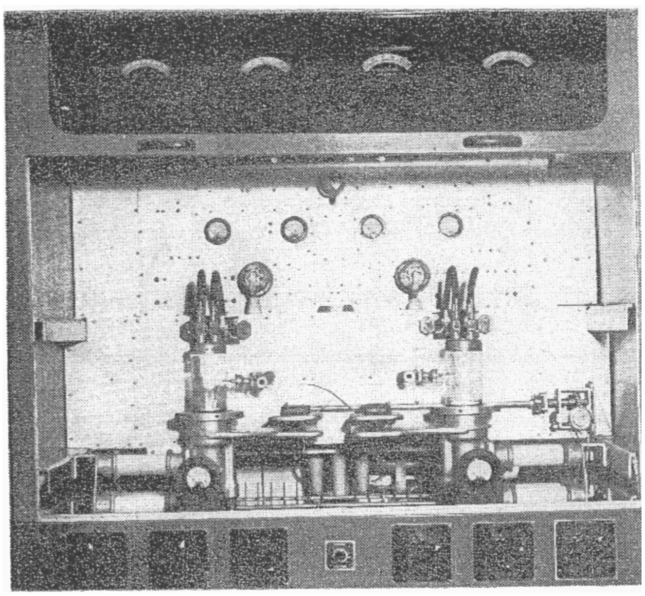


Figure 8. Front view of the RF driver shich is composed of three stages. Each stage is separately tuned in both grid and plate circuits and is link coupled to the succeeding stages.

The Transmission System

A general overall picture of the complete transmission system appears in the block diagram of Figure 3. The diagram shows one complete transmission system with its three essentials: primary power, rf power, af power, separately obtained and combined into high power modulated rf energy, which is radiated by the antenna system.

Radio frequency at carrier frequency is generated continuously on all frequencies assigned to this plant. Separate 15-Watt exciters for each frequency are mounted, six to a bay, in the control room. Exciter power is fed to the transmitters through a plug and jack panel, using multiple, double conductor coaxial lines and jacks.

The rf driver unit, third from the left in Figure 4, operates at carrier frequency throughout. Its range is 6 to 22 mc. Input power from the exciters is from 2 to· 5 watts. A maximum output power of 10 kW can· be obtained from this unit, which is coupled, through an adjustable link, to the power amplifier in the adjacent cabinet to the right.

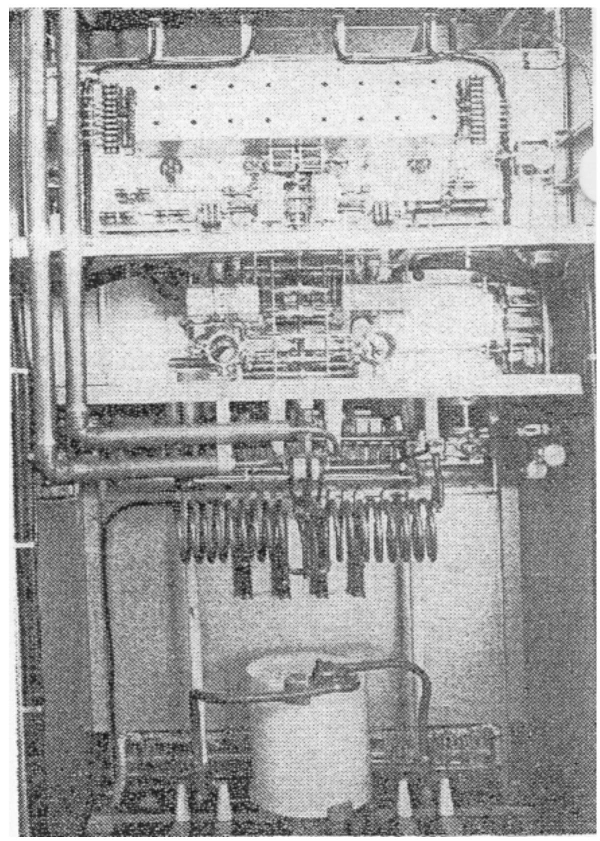


Figure 9. Output coupling adjustment, which is completed by swinging a small link coil into the field of the center of the driver plate inductance.

The modulated class. C amplifier employs. two tubes, operating push-pull, capable of 200 kW carrier output. Conventional lumped constant circuits are ulsd in the grid while the plate circuit consists of a lumped variable capacity, and a shorted transmission line section for the inductance. Variable inductive coupling is employed to transfer power to the antenna transmission lines.

The a-f circuits originate in the control. room, where the modulating signal is taken from incoming telephone lines or local electrical transcriptions. A transmitter circuit includes a limiting line amplifier, to amplify the audio voltage and compress high level peak; peak clipper to chop both positive and negative peaks at a pre-set level, usually equivalent to 100% transmitter modulation; and the usual level controls and volume indicators, From the control room, a-f voltage is fed at zero level to the modulator unit of the transmitter. The modulator contains three push-pull voltage-amplifier stages; and a multiple-tube class *B* power stage capable of delivering 180 kW of audio power, The modulation transformer, modulation reactor, anti do blocking condenser are located in the transformer vault, and are connected to the modulator through high~voltage cables.

Primary power for these transmitters is derived from· a substation at the side of the main building, and a stepdown transfomler in the transformer vault. All rectifier tubes and their filament transformers are located in the rectifier unit of the transmitter,
The rectifier unit also serves as a control and supervisory unit for the entire transmitter. Momentary contact buttoos, pilot relays, and supervisory relays and lights are mounted in the rectifier cabinet, All 240-V power contactors for filaments, low voltage supplies, etc., and a 240-V breaker and distribution panel are located in the wall cabinet behind the transmitter, as previously described, All equipment dangerous to personnel is compltely interlocked, both electrically and mechankally,

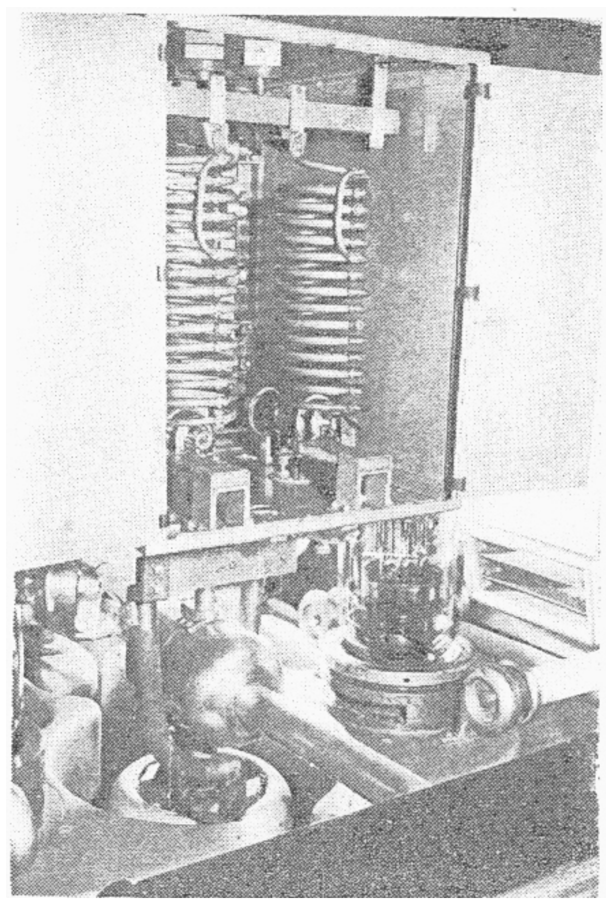
Antenna System

The antenna system consists. of a transmission line from each of the six transmitter bays to a common transmission line switching systein. In this gear any transmitter line can be connected to any outgoing antemta line. All antennas are of the reentrant rhombic type.

Each transmitter is equipped with a complete and separate cooling system, which supplies water for water-cooled tubes, ane! ventilating air for general cahinet· cooling. This system is so arranged that all waste power is converted into heated air, which is automatically used for building heat in winter. In summer, heated air is forced through roof ventilators. causing cool air to be drawn into the building. A 50-gallon-per-hour still in the boiler room and a 400-gal!on storage tank in the guard tower with a common feeder to all systems, supply the distilled water for cooling.

A complete system. of modulation monitoring, by means of oscilloscopes, of audio monitoring by means of diodes on the transmission lines, and of frequency monitoring, by means of a secondary standard and WWV comparison equipment is centrally located in the control room.

Figure 10. Interior of the power amplifier cabinet. Small cabinet between the two tubes provides shielding for grid circuits of amplifier.



R-F Generator

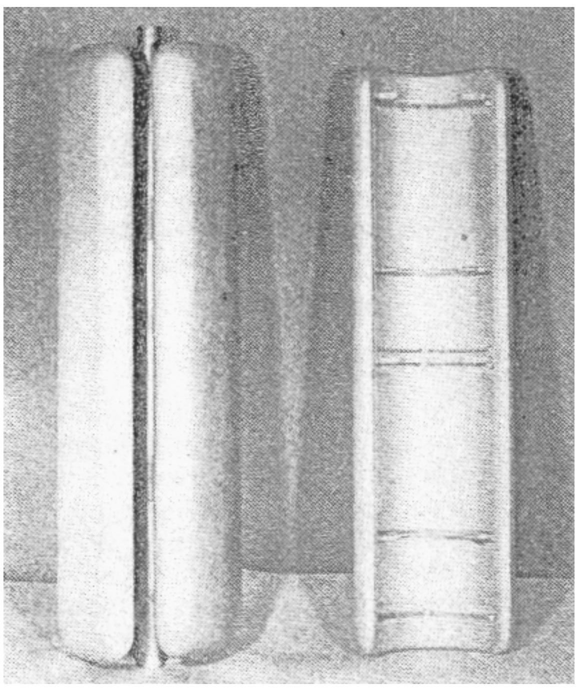
The r-f signal is initiated in the r-f generator units. A battery of these run continuously. All units are identical, consisting of a 6V6 crystal-oscillator stage, two 6V6 multiplier-buffer stages and a final 807 amplifier.

The crystal-oscillator stage is of conventional design, using broadcast-type temperature controlled ovens. The plate circuit is tuned to crystal frequency, The first buffer stage operates either at crystal frequency of second, third or fourth harmonic, and the second buffer stage operates in some cases as a multiplier and in other cases as a straight amplifier, depending on the multiplication of crystal frequency required.

In all cases the 807 stage operates as a straight amplifier. The output is coupled to three parallel sets of coaxial jacks. Operating conditions are such that from one to three transmitters may be connected without affecting the drive.

Each unit is assembled on a rackmounting 12 x 20" chassis. all of which are identical. Thus any unit can operate on any frequency, when proper coils and crystals are plugged in.

Figure 11. Neutralizing condenser, which consists of two semi-cylindrical sections, rotated in the cylindrical space formed by the tube jacket housings.

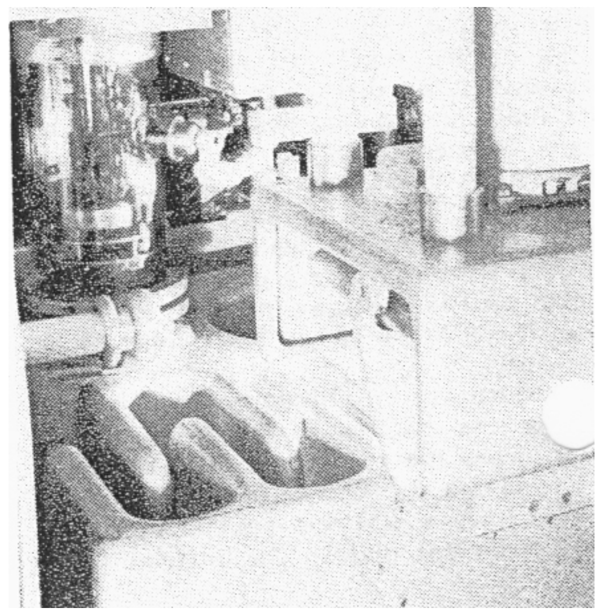


Tuning the crystal oscillator and. buffer amplifier stages is accomplished by midget variable condensers mounted inside the coil forms. The tuning condenser for the plate circuit of the 807 stage is mounted in the chassis, and is adjustable from the front panel. Thus, to set up any unit on a given frequency, it is necessary only to plug in the proper coils and crystal, and peak the tuning of the 807 stage. Figure 5 shows a rear view of one of the r-f generator units. The shield has been removed from the second buffer stage coil to show the construction.

A partial view of the equipment bays in which these generators are mounted appears in Figure 6, showing the coaxial patching panels by means of which the outputs of the generators may be patched to the inputs of the transmitter drivers. Immediately above and below the patching panels are the r-f generator unit front panels (one of which has been removed to show internal construction) with the final tuning knob to the right, tube metering; push buttons grouped at the center, and crystal heat indicator at the left.

Figure 12. Variable air condenser and transmission line inductance, with movable shorting bar in plate tank circuit of the power amplifier.

Audio monitoring of the transmitters is



accomplished by speakers concealed above each transmitter. Each speaker is driven from its own amplifier. The input to this amplifier is normally fed from a diode monitor coupled to the transmitter output. By means of a switch located on the hand rail in front the transmitter, speakers may be switched to the audio line so that comparison may be made between the signal as it enters the modulator input and as it leaves the transmitter. Duplicate speakers are similarly located in the control room above the control desk, where monitoring is accomplished in the same manner. In addition, there are monitor level controls on the desk.

Cathode-ray oscilloscopes, which may be seen in Figure 7, are provided for monitoring the carrier of each transmitter, and are located in the control desk. These have a 60-cycle sweep voltage on the horizontal plates; the vertical plates are fed from pre-tuned circuits, coupled by coaxial lines to the transmitter output. These tuned circuits are selected by band switch from the front of the oscilloscope The coil assembly on each has 10 resonant circuits, each with a midget variable condenser for resonating the circuit to any of ·10 frequencies on which the associated transmitter may be operating.

Immediately below each oscilloscope panel is a small panel bearing the audio level control, the *carrier-on.* light, the *emergency-off* button for each of the transmitters, and a key which, when thrown, drops the studio line, and picks up the output of a pre-set electrical transcription machine, and simultaneously, through relays, starts the transcription machine motor. To the right of the public address speaker on the center panel is a master key, which operates all the pre-set electrical transcription machines simultaneously.

At the center of the desk are the general· controls common to all transmitters. Immediately above is the public address speaker, which also serves as a microphone, and which may be switched to a two-way· f-m transmitter, communicating with the· antenna service car, without being disconnected from the regular building intercommunication system. Immediately below the speaker is a volume level indicator, with its range switch and channel selector switch. Below these are the level control and selector switches for the monitoring speakers.

The frequency monitoring system is also included in the control room equipment, and consists of a secondary frequency standard. a fixed-tuned 5-mc WWV receiver a frequency counter, and an r-f signal mixing panel.

All components of the 100 kc oscillator circuit are enclosed in a temperature controlled oven, including the tuned circuit, the crystal, the oscillator tube, and a voltage regulator. The oscillator is electron coupled to an isolating amplifier, which feeds the output to the multivibrator and the fixed tuned WWV receiver.

The WWV receiver is a three-stage t-r-f type, fed from a tuned loop. A detector stage mixes the 100-kc signal with the WWV signal. An audio amplifier is included to drive the monitoring speaker.

The multivibrator is of conventional design, with operating frequencies at 10, 20 and 50 kc. It is preceded and followed by isolating amplifiers. The output amplifier is of cathode-follower type, feeding one stator of two signal-balancing variocouplers, in tandem, driven from a common shaft, and completely shielded from each other. A faraday shield eliminates capacity coupling between rotor and stator of each variocoupler. The rotors are so oriented on the common shaft that when coupling is at minimum in one unit, it is at maximum in the other. Multivibrator output is fed to one stator the unknown signal is fed to the other: and the two rotors in series are fed to the input of the communications receiver. This provides a means of balancing the amplitudes of the unknown and the standard signals. so that a good beat note is obtained.

The unknown signal input to the signal balancing variocouplers may, by means of a jack. panel, be obtained from one of the r-f generators, or from an antenna. The multiple-band communication receiver and frequency counter complete the equipment of the frequency-monitoring unit.

R-F Driver

A front view of the r-f driver, which is composed of three stages, is shown in Fig. 8. Each stage is separately tuned in both grid and plate circuits, and is link coupled to the succeeding stage. Both the grid and plate circuits of the first stage, a single 807, have eight pre-tuned, plug-in coils. Each grid coil is provided with an input winding which is selectively connected to the double coaxial transmission line terminating on the r-f exciter patching panel. The push-pull 813 second stage has two sets of tapped coils in both grid and plate circuits.. The Fl29B driver third stage is push-pull, and has two sets of tapped coils in its grid. Both these stages have adjustable tuning capacities, controlled from the front of the cabinet. The F129B plate circuit consists of a copper tubing' inductance with adjustable taps and shorting bars, and a variable air condenser, visible from' center front of Figure 8, controlled from front of cabinet. A ganged band switch is mounted vertically and operated from the rear of. the cabinet by means of a horizontal handwheel, accessible from the top shelf. This mechanism switches all circuits except the F129B plate circuit, which must be changed manually , Other front controls include the third stage neutralizing, and. the output coupling adjustment which is accomplished by swinging a small link coil into the field of the center of the driver plate inductance, Figure 9.

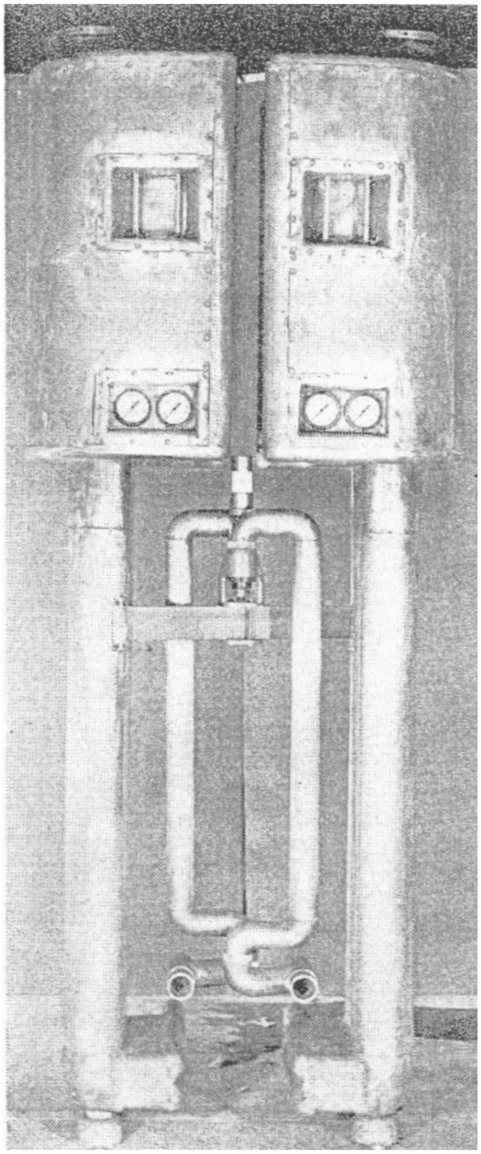


Figure 13. Vertical adjustable portion of the coupling loop, which also has a horizontal fixed portion running parallel to the horizontal portion of the transmission line tank circuit.

Final Amplifier Unit

The final amplifier of each transmitter is designed to deliver 250-kw 100% plate modulated, on frequencies between 6 mc and 21.65 mc, with plate voltage up to 15 kV. Figure 10 shows a view of the Interior of the power amplifier cabinet. Mounted between the two tubes is a small cabinet which provides shielding for the grid circuits of the amplifier. The grids of these tubes are driven through a pi network, fed through coaxial transmission lines from the driver cabinet, where it is inductively coupled to the tank circuit of the driver. The doors of the grid cabinet are shown open, so that grid coils may be observed. These coils are so proportioned that the circuit is tuned at 6 mc, when the entire coil is in the circuit. By placing shorting straps across turns of the coils, higher frequencies are obtained, until at 21.65 mc the entire coil is short circuited. The pi network uses the tube capacities and inductances in its circuit.

The· grid circuit of the final amplifier has a fixed bias which protects the tubes to a safe value of plate dissipation, in case of failure of drive. This is accomplished by obtaining bias voltage through a high resistance from one of the low voltage rectifiers. The voltage is applied continuously, and in case of failure of drive, the tubes are automatically protected from overloads without. the operation of any relays. When tubes are being driven, the bias becomes negligible.

On each side of the cabinet interior, cooling air is provided through a vertical duct, connecting with the header duct above the entire transmitter unit, and providing a blast of air on the glass of the power amplifier tubes, of sufficient velocity for effective cooling over the entire periphery of the glass.

In Figure 10, the arrangement of the neutralizing condenser and the plate tank condenser may also be seen. In the center of the picture, three concentric shafts run toward the rear of the cabinet, through a corona shield, housing bevel gears. This mechanism, operating. by chain drive from controls on front of the cabinet, adjusts the plate tank condenser, the antenna coupling loop, and the neutralizing condenser.

The neutralizing condenser consists of two semi-cylindrical sections (Figure 11) rotated in the cylindrical space formed by the tube jacket housings. This design provides a balanced-bridge circuit, with essentially no detuning of grid or plate circuits during neutralization adjustments.

The plate tank circuit of the power amplifier (Figure 12) consists of a variable air condenser and a transmission line inductance with movable shorting bar. The constants of this circuit are such that a frequency range of 6 to 21.65 mc is covered by adjustment of the capacity and inductance. The moving portion of the plate tank condenser is suspended from a carriage which rides on three brass pipes. In addition, this condenser is bypassed to the shield at practically the same point to which the filaments of the tubes are bypassed. The grid cabinet is also connected to this same point. This serves to hold the circulating currents in the shielding to a minimum, and provides stable operation at powers in excess of 200 kW.

The stationary plates of the plate condenser are carried directly on the housings which contain the tube jackets. Figure 13 shows an assembly of tube jackets in housings, incorporating thermometers and water pressure gauges. Also .shown are the antenna coupling loop, vertical section of the transmission line, and the bottom header castings to which are to be connected the horizontal four-pipe transmission line, on which the shorting bar slides. These horizontal pipes also carry cooling water to the tubes.

The transmission line tank is housed in a metal shielding duct, which is a continuation of a shield within the cabinet, but which is insulated from the metal of the cabinet itself. The vertical section of the transmission line consists of a pair of large copper pipes on each side, each pair encased in a. copper sleeve. This offers an exceptionally low impedance circuit, and makes it possible to obtain a high distributed capacity, even though the conductors are separated from each other far enough to permit mounting of a coupling loop between them.

The coupling loop is in two portions: a vertical adjustable portion shown in Figure 13, and a horizontal fixed portion which runs parallel to the horizontal portion of the transmission line tank circuit, and which is automatically coupled or decoupled, depending on the position of the transmission line shorting bar. Tuning of this coupled circuit is accomplished by vacuum condensers, either at the bottom of the vertical coupling loop, or at the rear of its horizontal portion, depending on frequency. The vertical portion of the coupling loop is so arranged that it can be rotated into a bucking position with respect to the horizontal section, during operation at lower frequencies .

All of the foregoing adjustments for frequency change can be made from the front of the cabinet in a few seconds.

Low Level Audio and Control Room Equipment

All program material is supplied to the transmitters either by telephone circuits, or by electrical transcriptions. No provisions are made for live pick-ups at the transmitter building. At present the OWI and CIAA programs originate in studios in the East, and are fed through the WLW master control room at Crosley Square in downtown Cincinnati, to the transmitter audio equipment. Figure 14 shows a panoramic view of the equipment bays in the control room. A separate amplifier channel is provided for each modulator input, plus one spare. Each channel is installed in a separate equipment bay.

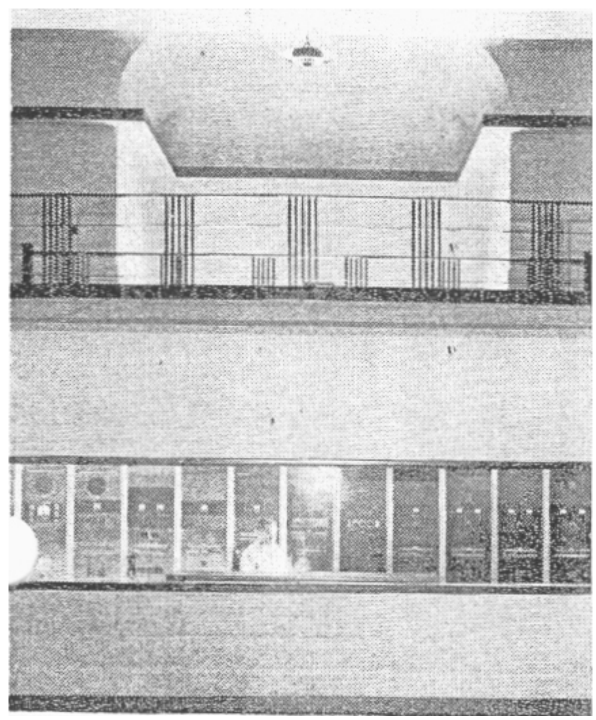


Figure 14. View of the equipment bays in the control room.

The incoming lines are terminated in matching networks which provide a means of feeding one to three amplifier channels from any one line. The output of the matching network may be patched directly to the desired amplifier input, or it may be patched through a selector switch, affording a quick means of transfer from one program channel to another. This switch affords a selection of either of two circuits, and is set up by patch cord, so that the selection may be between any two telephone lines, or between telephone line and electrical transcription output.

The signal then is routed to one of four equipment bays which contain the amplifier channels associated with the particular transmitter inputs, and passes through a variable attenuator and all electrical transcription switching relay to the line amplifier. The volume indicator, mounted . in the bay, monitors the level at the output of the line amplifier. From this point, the signal passes through a peak clipper, and out of the amplifier bay to the transmitter input attenuator, located on the control desk.

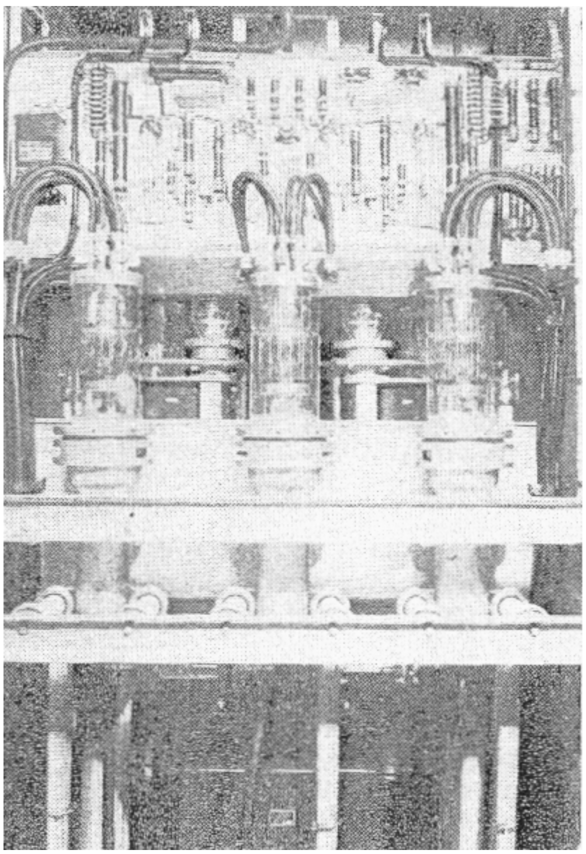


Figure 16. The 42 Ohm surge-limiting resistors which are in series with each modulator plate circuit, at bottom of unit in view below.

The electrical transcription switching relay mentioned, is controlled by keys on the control desk, as previously described. Monitoring speaker amplifiers and switching equipment are also located in the control room equipment bays. Each program channel has a monitoring take-off at the output of the line amplifier, and this signal is fed through speaker selector switches so arranged that the operator is able to pre-set levels before the signal is fed to the modulator input. The e-t machine output is fed through a pre-amplifier and variable attenuator to the switching relay, and to the selector switches of the monitoring speaker, so that here again the level may be pre-adjusted before the signal is fed to the modulator.

Throughout all of the speech equipment in the control room, complete flexibility is maintained by use of jacks and patch cords, by which any elements, from amplifiers to fixed pads,. may be isolated. In most cases, back contacts on the jacks route the signal through its normal channel, but the presence of the jacks in the circuit makes it possible to lift a defective element quickly, and patch in a spare.

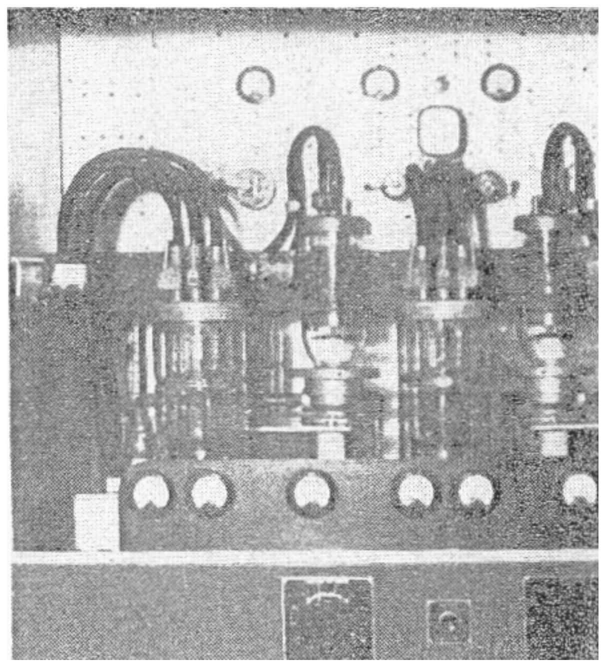


Figure 15. Modulator unit which consists of a three-stage voltage amplifier and a two to six-tube class *B* amplifier.

Modulator

The modulator (Figure 15) consists of a three-stage voltage amplifier, followed by a 2- to 6-tube class *B* power stage. The first two stages are push-pull 807 and 813 tubes, respectively, and are resistance coupled. These stages are mounted horizontally on a vertical panel in the upper center of the unit, while the circuit components are mounted on the rear. The 813s are resistance coupled to push-pull 891s, located slightly above the main group of tubes, and operating class *A* as the third voltage amplifier.

The 891 stage is coupled with a 1:1 ratio transformer to 2, 4, or 6 F125 tubes, operating class *B* with zero-grid current, as the power stage. In the 4 or 6 tube arrangement, 2 or ·3 tubes operate in parallel on each side of the push-pull circuit. Three 125s in the front constitute one side of the class *B* stage, while three more in the rear constitute the other side.

In order to accommodate tubes of normal differences in characteristics, each tube has individually combined bias and drive adjustment. The circuit is such that these two adjustments are accomplished simultaneously, with one potentiometer in each grid circuit. .Each modulator tube plate circuit has a 42 Ohm surge limiting resistor in series, which may be seen at bottom of unit in Figure 16.

The modulation transformer, weighing more than 24,000 pounds, and its reactor and dc blocking-condenser, are located in the transformer vault. This combination was designed to cover a frequency range of from 50 to 10,000 cycles, at a power output of 180 kW maximum.

Power Supply Substation

Power is supplied to the plant from a 33-kV loop circuit, with remote controlled disconnect switches on each side of the take-off point. These switches, both normally dosed, may be opened by pushbutton controls in the transmitter control room, in case of a fault on either line.

At the substation a 3000-kVA transformer bank provides 3·phase, 2400 Volt service, divided into six main circuits to the transmitters, each equipped with fused disconnect switches; Three of these are for the high-voltage plate-supply transformers, and the other three are fed through an induction regulator, and supply a 200-kVA, 2400/240-V, 3-phase transformer in each vault. All 240-V power for operating filament transformers, pump and blower motors, low voltage supplies. etc., is obtained from these transformers. Each transmitter becomes an independent unit from the substation to the antenna switching station.

Transformer Vault

All high voltage transformers, filter reactors, filter condensers, and high-voltage control components are located in three fireproof vaults within the building, one for each of the three transmitters, built into the bay directly behind each transmitter unit. In the floor plan (Figure 2) the location of the vaults and the major components of one vault: may he seen.

The high-voltage plate transformer is a 750-kVA, three-phase unit. with a special high speed motor-operated tap switch, connected in its secondary winding, which operates under load. The transformer windings and taps are such as to provide variable dc voltages at the load from 5500 to 15,000-V in 32 steps. Incorporated in the transformer is a voltage regulating control, to operate the tap switch motor, and thus maintain the voltage at any selected value, regardless of input line variations or load on the transformer. Voltage adjustment is accomplished from the transmitter control panel, by means of a rheostat, which is the series calibrating resistor for the contact-making voltmeter in the control unit. The shaft of the rheostat is connected to the panel control through a torque switch, which causes the tap changer to become instantly responsive to adjustments of the control. At all other times, a half-minute time delay is automatically operative, as the tap· changer corrects for line voltage fluctuations. The transformer also returns automatically to its lowest voltage tap each time primary voltage is removed for periods in excess of a few seconds in order that reapplication of power may occur at minimum voltage.

The unregulated three-phase power for the high voltage system from the substation is fed through manual disconnect switches in the. vaults, and then through series line reactors for limiting fault. or rectifier arc-back currents, through a magnetically operated contactor, and· the ignitron interrupter *(see' high voltage controls)* before reaching the tap changing transformer. Normally, the magnetic contactor remains closed, and the power interruption is accomplished by the ignitron unit. But if an a-c line overload should occur or a transmitter door should be opened, this contactor operates, following the ignitron interruption, to provide additional protection.

The high-voltage supply filter consists of a .5/2 henry reactor. and 20 mfd of 20,000-V condensers. Power from filter is distributed to other components in the vault on copper buses. All d-c: power circuits to the r-f section have series surge-limiting resistors, and magnetically operates isolation switches, which are mounted on the vault walls, The 24-Ohm surge-limiting resistor for the final amplifier is a bank of edgewise wound resistors, mounted in a rack. For the lower voltage circuits, standard openwound resistors are used. The isolation switches are standard 25,000-V 3-ampere single pole switches with arcing horns added to minimize burning of the contacts. The bias-power supply consists of a 7.5-kVA transformer, with 2-10 henry 2.5-ampere chokes in the full-tap circuit. and a .5-ampere 10-henry choke in the half-tap circuit. With only the low voltage and bias supplies operating, the a-c power for the latter is fed through the 240-V breaker panel; but when the high voltage power supply is energized, the power is fed through a 7.5-kVA step-down transformer from the secondary of the 750-kVA plate transformer, which causes the bias voltage to vary directly in proportion to the changes in the high voltage supply. The low voltage supply uses a 5-kVA transformer, and the same size filter chokes as the bias supply. The dc power from the low voltage and bias supplies also incorporate a set of surge resistors and standard three-pole isolation switches.

All of the condensers used in the power supplies are equipped with a special fuse mechanism, which automatically disconnects a faulty condenser from the bank, and places a short across it.

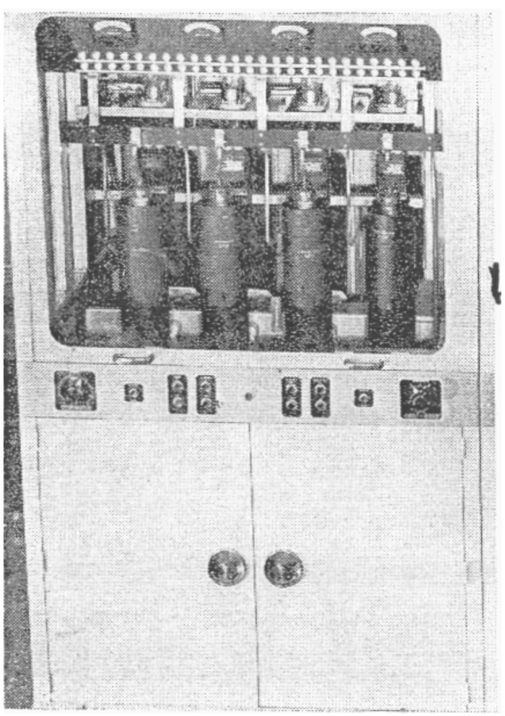
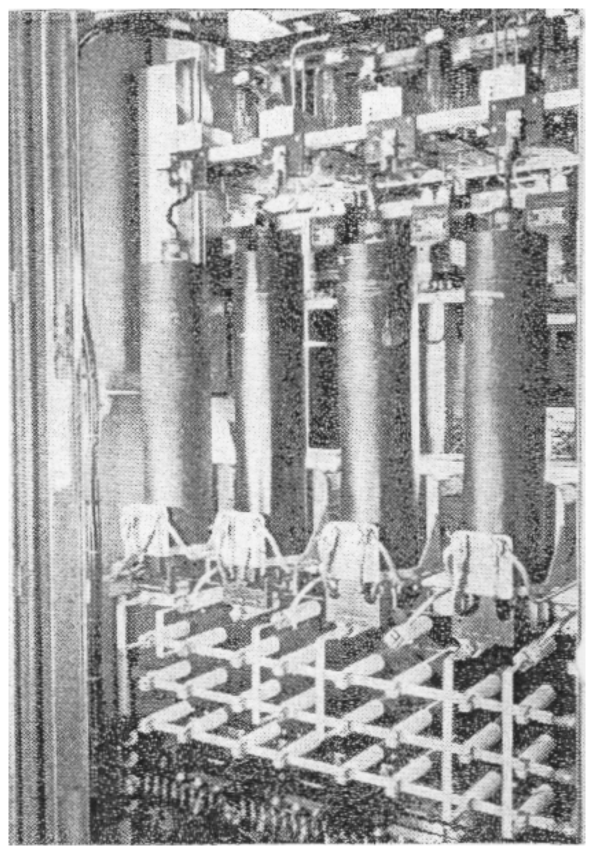


Figure 17. The rectifier cabinet.

Rectifier Cabinet

The rectifier cabinet (Figure 17) contains three rectifiers. two of which are low voltage bridge circuits, one providing bias voltages of 2000 and 4000 V, and the other providing plate voltages of 1000 and 2000 V. The third rectifier is the high voltage six-phase single *Y* circuit, employing six 870A tubes, and provides plate voltage for the modulator and final amplifier. Two spare 870 tubes are kept continuously heated, making a total of eight tubes, all of which are mounted on a thermostatically-controlled air duct, with nozzles blowing on their individual mercury radiators. This duct is supplied from a vertical duct in which are mounted strip heaters and their control switches, and which connects with the overhead cold air supply.

Figure 18. Tube switching panel.



Below the tubes, at the rear of the cabinet, (Figure 18) is a tube switching panel, so arranged as to make switching of spare tubes into the circuit an error proof procedure. Six of the eight tubes are always connected into the circuit by means of six jumper straps, in pairs of three different lengths, no two of which are identical due to the left or right twist of the top end of each strap. The upper switch jaws just below the tubes are mounted at corresponding angles, slanting alternately left and right, and connecting alternately to cathodes and anodes of all eight tubes.

When· a fault occurs, the annunciator light on the front meter panel indicates which tube is defective, and it is necessary only to remove the corresponding jumper strap and insert it into the only vacant position into which it will fit. This arrangement provides one spare tube each for the parallel cathode side and the parallel anode side· of the circuit. Below this switching panel are mounted the high-leakage reactance-type filament transformers for the 870 tubes, which automatically limit starting filament current.

Tube Cooling

The heat dissipation system consists of a separate blown-air and water cooling system for each transmitter. The fan and pumping equipment for each unit is housed in the fan room directly behind the unit. Each system is. designed to dissipate 350 kW of electrical power, and provide for removal of waste heat in the transmitter cabinets and high velocity air for cooling the mercury radiators on the high voltage rectifier tubes; as welt cooling water to the ignitron. units. The system is also arranged to furnish *byproduct* ventilation of the building in summer, and heating of the building in winter. Auxiliary steam coils are installed in connection with the air units, to operate automatically when there is insufficient waste electrical heat for adequate building heating.

Each fan room .is equipped witb two double-inlet, double-width centrifugal fans, individually motor driven. The fan suction plenum is connected through dampers to a filtered outdoor air plenum. to the building concourse, and to a recirculated warm air· bypass. The fans discharge the air through four, finned copper, distilled water cooling coils, from where the heated air is wasted to atmosphere or delivered to the building for recirculation. Forced air ventilation for the transmitter cabinets and ignitron cooling system is taken directly from the fan discharge plenum which is maintained at constant pressure. An evaporative cooling section is provided for the ignitron unit to supply water at lower temperature for this unit. The remainder of the system utilizes dry air cooling to obviate maintenance of coil surfaces and attendant spray water nuisances.

Each transmitter is equipped with a separate distilled-water circulating system. The pump is of the horizontally split case type, direct connected to a 1750-rpm motor. The pump takes its suction from an open surge tank and discharges the water through the tinned cooling coils previously mentioned. From here it goes to a distributing supply header below the transmitter cabinets. where it is fed through individual circuits to the various tube jackets and coils. The heated water is then collected in a similar supply header which carries it back to the surge tank, which serves as an air release and automatic make-up chamber. A similar system of much smaller capacity is used for the ignitron system.

Water is distilled in a 50-gallon-per-hour capacity still in the boiler room and is pumped from there to a gravity tank in the tower, then to the various surge tanks. The still is operated by steam from the heating boilers.

A complete pneumatic control system operates the various dampers in the blown-air system, from a master panel housed in the main control center at the rear of each transmitter unit. Flow meters, pressure gauges and thermometers are conveniently located on the slanting front edge of the transmitter catwalk, so the operator can instantly determine the water flow and air and water temperature at critical points in each circuit.

Since the complete transmitter unit is composed of two r-f sections, one power supply and one modulator, the control circuit had to be arranged to provide for individual or simultaneous operation of the r-f sections. As it is set up, either r-f section can be operated as an individual transmitter, or both can be operated from the common power supply and modulator. In case of a fault or tube overload when both units are in operation, automatic isolation of the units is provided, to minimize loss of air time of the unit in operating condition.

The heart of the control system is located in the rectifier cabinet, and each function in the operation is initiated from the push button on the front control panel. The relay panel contains the primary-control relays plus the annunciator relays. On the meter panel at the top of the rectifier cabinet. a set of 50 annunciator lights indicate open transmitter or vault doors, and the operation of overload relays, each of which has an associated annunciator relay, which locks up after a fault occurs, lighting the corresponding annunciator light until a reset button is pushed. Another button closes all annunciator relays to test for burned out lights.

For checking faults in the control system. a series of 40 small 1/25-watt neon lights are provided on the annunciator relay chassis, each of which is connected across a particular set of overload relay contacts, door interlocks, or control relay contacts, so that in normal operation none of the lights would be lit; but, if a fault occurs, the neon light number, in conjunction with a chart, tells which circuit is open. In turn, each overload relay has a neon light across its contacts, so the exact location of the trouble can be determined quickly.

This same equipment is duplicated in a dummy rectifier cabinet in the companion transmitter on the opposite side of the concourse, both operating with a common power supply and modulator.

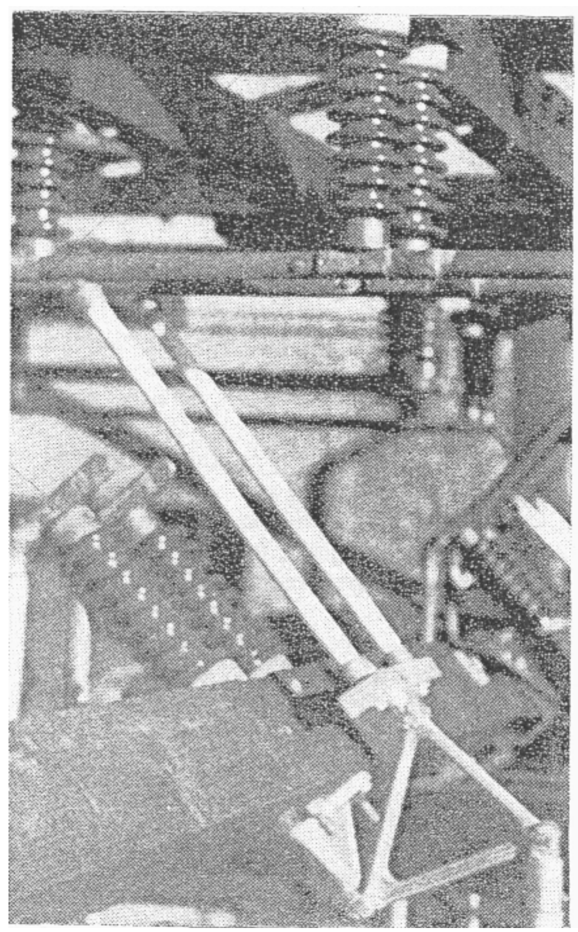
All overload and arc-back relays, with the exception of the high-current delayed a-c overloads, are. dc telephone type relays, with special coil and contact insulation. The coil of the relay is in series with a current adjusting rheostat, and this combination is shunted by another resistance of the proper value for the protected circuit. This is a very flexible and satisfactory means of overload protection. Because of high operating speed. this type of relay gives better protection than the standard overload device. In eases where the coil must be at a high potential to ground, such as for arc-back protection of the rectifier tubes, the contacts are removed from the frame and operated by an insulating rod.

All 240-V power is fed through a breaker panel in the wall cabinet behind the transmitters, and then through contactors which are operated by relays of the control circuit.

Filament Control

Conventional water flow and water temperature protection are provided in the filament circuits. Distilled water pumps, fans and filaments are controlled by the first pair of push buttons on the panel. A time delay provision is incorporated, to continue operation of pumps and fans until 15 minutes after· filament shutdown. In addition, filament switches are provided for individual water-cooled tubes or banks of tubes (depending on number of tubes in series on one water circuit), which permit changing of tubes without turning off all tube filaments. These switches control the primary power contactor, and short out the water flow interlocks associated with each particular tube or bank of tubes. The circuit is so arranged that turning on the filaments of the separate r-f section also turns on the filaments of the main transmitter, since the modulator and rectifier are needed for its operation. Conversely. turtling off the filaments of the main transmitter turns off the filaments of both units.

Figure 19. Elements composing the antenna switch. They



are the same diameter and spacing as pipe conductors connected to switch.

Low Voltage and Bias Control

The second pair of push buttons provide control for the low voltage and bias systems. The interlock system is divided into three sections, one of which contains the door interlock switches of the rectifier, modulator, catwalk and transformer vault, and the overload relays. contacts associated with these units, In series with this are the interlocks and overload relay contacts for each of the r-f sections, An emergency *off* push button is located in the center of the control panel of each cabinet. These are also in series with the interlocks. Magnetically controlled isolation switches are used to remove the d-c voltage from an r-f section when not in use, or if a failure in one should occur while both are on the air. These switches are designed to break circuits with the power on. The a-c power for the bias supply is fed through the same contactor that supplies the low voltage power, when the low and bias voltage supplies are first turned on. However, when high voltage is turned on, the bias power is obtained as described in the discussion of the transformer vault.

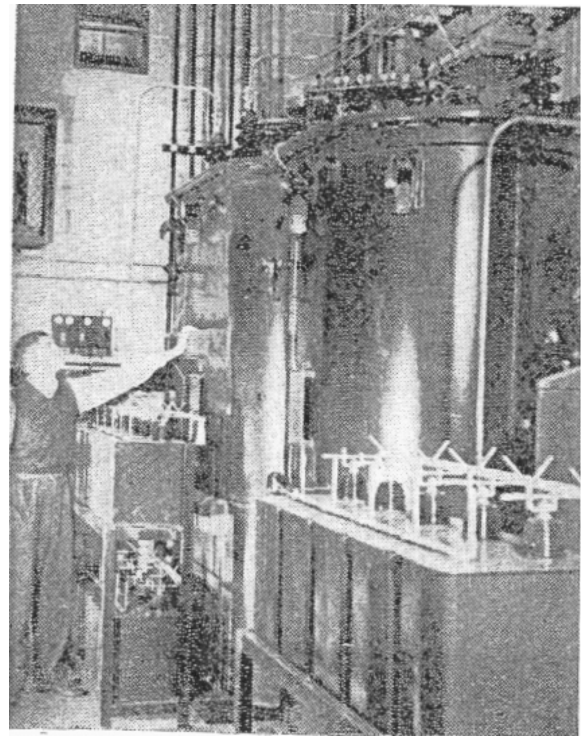
Bias switching is accomplished with a fast-operating reversing contactor, mechanically interlocked to prevent an interconnection of the power sources.

High Voltage Controls

All unusual feature of this system is the anti-pumping circuit. Should a fault occur while the *on* push button is held down. the power supply interrupter has only one closure, and will not reclose until the button is released and pushed again.

D-c voltage to both the r-f driver and final amplifier is fed through individual magnetically operated high-voltage isolation switches. The control of these switches is arranged to operate only when the d-c voltage is off. Thus. if one r-f section is turned on while the other is operating, the power supply shuts down long enough for switching to take place, then automatically comes on again. The same occurs if one of the units is turned off, or if an overload occurs in either section .To facilitate neutralizing of the final amplifier, a switch is provided on the relay panel of this cabinet for individual control of the isolation switch, thus removing high voltage from the unit. and permitting it to be applied to all other units.

Figure 20. A view of one of the transformer vaults.



The Ignitron

Another novel feature of this installation is the use of the ignitron as the 2300-V high-speed circuit breaker. The overload-relays protecting equipment connected with the high voltage supply have one set of contacts in a conventional interlock circuit, which serves to remove power supplying the thyratrons which ignite the ignitrons. A second set serves to bias the thyratrons in advance of removing power, so that if an overload occurs, there is all . almost instantaneous interruption of power; many times faster than with conventional a-c relays. The control system is, of course, tripped by the first set of contacts when a fault occurs, and interrupts the control voltage for the ignitron. Thus, two means have been included to insure shutdown of the high voltage supply, making a high-speed circuit that operates in 3 to 10 milliseconds after the overload relay operates, depending on· the portion of the cycle the ignitron is passing at the time. The average time of the telephone-type overload relay used is about 5 milliseconds. Thus the overall time for interruption of power is only a fraction of that required for the conventional overload relay and air or oil-circuit breaker.

The high-voltage tap changer remote rheostat, with its associated torque switch and front panel control, as previously explained, is duplicated in the "dummy" cabinet on the opposite side of the concourse. Associated with this control on both main and dummy rectifier cabinets is a push-button to switch the tap changer control circuits from one rheostat to the other.

Automatic Reset

The fourth pair of push buttons on the control pane! operate the automatic recloser circuit. When *on.* this circuit automatically reenergizes the power supply after an overload occurs, should a second overload occur, or the first fault still exist, within fifteen seconds, that particular r-f section in which the fault took place is isolated and the remainder of the transmitter turned on again. If no further trouble develops within that fifteen-second period, the system resets itself and is ready to operate again.

Carrier Alarm

A relav in the cathode circuit of one of the filial power amplifier tubes operates the carrier-alarm system. This relay is set so that it will pull in under normal operating conditions. but drop out if excitation or plate voltage should fail. And in conjunction with another relay, it operates the alarm, a warning light above each transmitter and a horn common to all six final amplifiers. If a transmitter goes off the air, the carrier alarm can be switched off temporarily, but becomes effective each time the transmitter is turned on.

Personnel Protection

For the safety of personnel, all equipment operating at high voltage is completely enclosed and interlocked. Each transmitter cabinet has a solenoid-operated shorting mechanism which grrounds all high voltage terminals in the cabinet when any cabinet door is opened. This is located in the upper part of the cabinet where it is easily visible from both front and rear. Catwalk grills and doors are interlocked to operate the shorting mechanism in the rectifier cabinet.

The high voltage components in the transformer vault are enclosed with wire fencing, Before this section of the vault can be entered. a lever must be thrown which operates disconnect and grounding switches, and a mechanical interlock on the cage and ignitron doors.

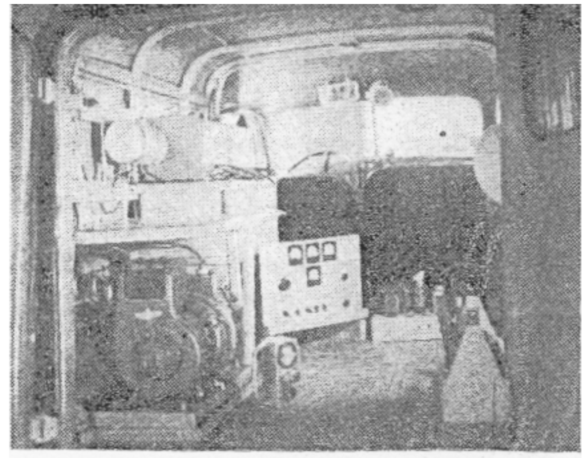


Figure 21. An interior view of the antenna service car. Equipment in this car includes two-way FM communications equipment , affording constant contact with the control room.

Transmission Lines

The transmission lines from the transmitters to the main antenna switching station are all of 300-Ohm surge impedance. The section leading out of the building is of 2" copper pipe in order to be self-supporting across 18' driveway clearance, and to present good corona conditions through the glass entrance pane. These pipes are spaced 13". From this point to the main switching station. the line consists of a 4-wire construction, using two pairs of 1/0 copper weld (each pair as one conductor). spaced 2-1/8" one above the other, and 7" between pairs, which is the same spacing as used in the 300-Ohm switch structure, where two l" copper pipes are used for each line. To maintain spacing between wires on each side of the line, cast clamps are used at intervals of about 10'.

To meet the requirements of multiple switching of antennas and transmitters at 200-kW powers, the following specifications had to be met in the design of the main antenna switching station:
(1)- Provision for. connecting any transmitter transmission line to any antenna transmission line.
(2)- Provision for unlimited expansion of number of transmitter and antenna transmission lines.
(3)- Maintenance of 300-Ohm impedance throughout, regardless of switching operations.
(4)- Elimination of all dead-end effects.
(5)- Provision for breaking up all unused lines to prevent possibility of resonance.
(6)- Simplicity of operation and identification for scheduled switching.

These requirements were met by designing a structure carrying incoming transmitter transmission lines on a lower level, and outgoing antenna transmission lines on a higher· level, at right angles with the incoming lines. Between these two levels are vertical spiral. riser lines, terminating top and bottom with double-pole, double-throw switches. On short posts near the ground are operating cranks, which operate the switches through mechanical linkage.

Electrically, all lines continue through the structure as long as. all switches are in horizontal position. Operation of a lower switch breaks the line at that point, and connects the transmitter with its vertical riser. Operation of the associated upper switch breaks the antenna line at this point and connects the antenna to the riser, thus completing the circuit from transmitter to antenna· No unused lines remain connected to the system to cause dead end effects. The unused lines which have been disconnected may be further broken up into shorter sections, if desired, by operating other switches beyond the point where the connection was made, in order to prevent any possible resonant effect.

As seen in Figure 19, the elements composing the switch are of the same diameter. and. spacing as the pipe conductors connected to the switch, providing constant impedance throughout the structure.

No limitations are imposed on possible future expansion, since it is necessary only to add more lines and switches as transmitters or antennas are addled.

Matching Section

Immediately upon leaving the main antenna-switching station, impedance matching sections arc inserted between the 300-Ohm gear and the 500-Ohm antenna transmission lines. These sections comprise 3 lines, each one-quarter wave long in tandem, varied in spacing; and conductor size to accomplish the transition. Two types are used: type *A* sections have a design frequency of 12.3 mc, and are connected to lines serving both large and small antennas requiring maximum frequency range of 6 to 18 mc; type *B* sections are designed at 13 mc. and are used in connection with lines serving antennas operated between 7.5 and 15.5 mc.

Transmission lines of 500 Ohms from these impedance matching sections to the antennas are, in some cases, as long as 3750'. To keep loss at a minimum consistent with cost and use of critical materials, 4-wire construction was used. consisting of two pairs of number 2 copper weld wire, each pair spaced 3/4" as one conductor, with 20" spacing between pairs. and with all four wires in the same horizontal plane. As in the case of the lines leading from the transmitter building, clamps maintain the 3/4" spacing.

Lines run at about 15' above ground in most places. Turns are accomplished by vertical spiraled jumpers to maintain equal conductor length and spacing. Where more than one transmission line is carried by the same pole line, a spacing of better than four times the 20" conductor spacing is maintained, to keep coupling at a reasonable minimum.

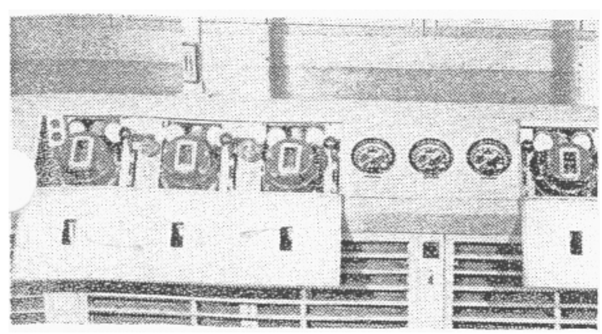


Figure 22. Water controls on front ledge of transmitter catwalk.

Line Switches

The 24 antennas are arranged in 9 groups, 6 of these containing 3 antennas each, the other 3 containing only 2 each. Each group is fed by a pair of transmission lines. In the case of the two-antenna groups, lines run directly from the switching station to the antennas; but in each of the 6 triple antenna groups, one transmission line runs from the switching station to the middle antenna, while the other is arranged to be switched between the small and the large antennas, since these two are never used simultaneously. A special double-pole, double-throw switch is located along the transmission line near the antennas, so constructed as to have 500-Ohm surge impedance. Thus no disturbance is introduced into the transmission system. The switch itself is located at transmission line level, and is operated through a mechanical linkage system by a lever at waist height.

Reentrant Rhombic Antennas

Because of relative ease and low cost of construction, amount of critical material required, and satisfactory performance over a rather wide frequency range. rhombic type antennas are used for the 24 radiators. Three sizes cover the frequency range of 6 to 18 mc. with adjacent size pairs being used simultaneously.

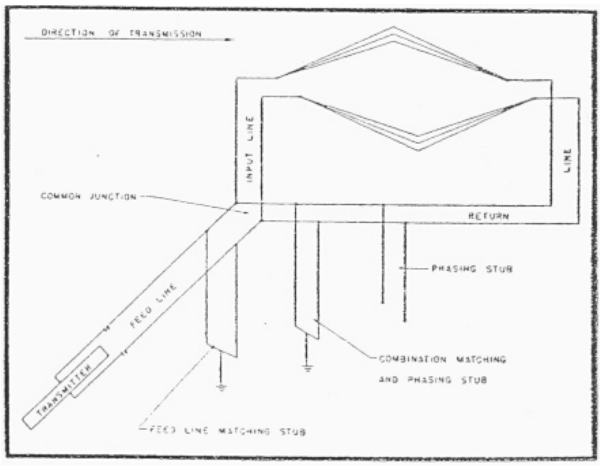


Figure 23. Rhombic antenna, showing reentrant feature and stub-tuning arrangement.

These three' sizes are designed at mid-frequencies of 16.33 mc. 11.67 mc, and 9.33 mc, with a low vertical angle of approximately 10˚ and a beam width of 20˚ at these frequencies. Antennas are four wavelengths long on each side, with a tilt angle of 70˚, and an average elevation of 1.4 wavelengths above ground. They are constructed of three number 6 copper weld wires on each side, spaced at the side poles, and converging to a point at each end. Due to low inherent coupling between adjacent rhombic antennas, common support poles were used between antennas. Each pole is actually two poles, spliced butt-to-butt with a steel sleeve. Poles rest in a 6" recess in a concrete base, and are guyed at three points.

In order to avoid wasting up to 50% of the power delivered to the antenna, by the conventional dissipative rhombic termination method. reentrant transmission lines have been incorporated, whereby the normally dissipated power is returned to the input line, properly phased and adjusted as to voltage magnitude, through the use of stub lines of the proper values and spacings along the return line. Impedance of the input line is corrected in a like manner, and in some cases combined with one of the reentrant stub lines. All stubs of the shorted variety are grounded at the midpoint of the short to provide static drain, and lightning protection.

Operation

Transmitters are scheduled in pairs, so that, as one frequency is becoming less effective in a chosen coverage area, the other is already in operation on the frequency next coming into maximum effectiveness.

To change frequency, two men are required to make the necessary technical adjustments in the short period allowed (usually 15 minutes). One man re-tunes the transmitter, and the other makes the necessary antenna changes and adjustments. The control operator shuts down the transmitter after the scheduled sign off, and disconnects the frequency generator which had been driving the transmitter, connecting it to the proper generator to supply the new frequency. This change is made on the r-f generator patching panel. Then he moves the dials on the transmitter unit to pre-determined settings. or changes pre-tuned coil condenser circuits as required for each stage of the transmitter, beginning with the lower power stages, and ending with the high power final stage and the adjustable antenna coupling loop.

While these adjustments are being made at the transmitter, the second man proceeds, in an antenna-service car, to the main switching station, where he connects the proper transmitter transmission line with the proper antenna transmission line. Then he proceeds to the antenna group. and connects the transmission line to the desired antennas through the line switches previously described. Finally, the proper stubs are inserted by use of switches, to adjust the antenna for its assigned operating frequency.

Upon completion of the necessary adjustments, he advises the transmitter operator, who is then ready to put the transmitter on the air on its new frequency.

Antenna Service Car

The car which is used for these operations is especially designed and equipped for antenna work. Its equipment includes a complete two-way f-m communications set, with which the technician is in constant communication with the control room.

The f-m receiver is just one part of the complete *intercom* system, which also includes telephones and public address systems. The combination of the three affords a complete and flexible means of communication between personnel anywhere on the property.

The public address system employs permanent-magnet speakers which serve both as speakers and microphones. These are located throughout the building; and at the main antenna switching station at the rear of the building. On the concourse, speakers are concealed above the transmitter units, with a switch key on the hand rail. At each of these positions, a key is also provided to mute the monitor to prevent interference with the public address speakers. When one of the concourse speakers is used as a microphone, the other five are silenced automatically by a relay, to avoid feed-back. The same system is used at the switching station, where there are six speakers.

The f-m system is tied into the public address system in such a way that any calls picked up on the receiver are fed directly into the publi address line. Through relay control, the f-m transmitter may be operated from the public address station at the control desk. The f-m system is used to maintain contact with the operator of the antenna service car, and with maintenance crews in the field.

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J. M. McDonald. assistant engineering director
W. A. Moore, chief design draftsman
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C. B. Sloan, design and development engineer
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P. A. Young, propagation engineer

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