Engineer of D.T. & I. locomotive No. 106 speaks over radio with Emery Lee, F.C.C. inspector, in Flat Rock yardmaster's office

D. T. & I. Tests Radio

Installation in highly industrial area features frequency modulation at 161.775 mc. as well as satellite transmitter-receiver station 14 miles from main station, and connected by 189 kc. carrier superimposed on the existing telegraph and telephone line wires paralleling the railroad

THE Detroit, Toledo & Ironton, in co-operation with the Farnsworth Television & Radio Corporation, has conducted extensive tests of very high frequency space radio telephone communication between locomotives and yard offices near Detroit, Mich. The territory extends about 14 miles north and east from the freight yards at Flat Rock to Dearborn and Delray, which are in the Detroit industrial area. The D.T.&I. has two lines, one extending from Flat Rock north and then northeast to the River Rouge Plant of the Ford Motor Company in Dearborn, and the second line runs east from Flat Rock to the Detroit river, then along the river front to yards at Wyandotte, Ecorse and Delray, the latter being east of Dearborn.

Northbound road trains of the D.T.&I. terminate at Flat Rock yard, and southbound road trains depart from this yard. Therefore, the delivery of cars from this yard to various yards, industries and connections, as well as the return of cars to the Flat Rock yard, is all handled by switching crews that work under the jurisdiction of the yardmaster at Flat Rock. The purpose of the tests, therefore, was to determine whether radio communication could be applied successfully to maintain two-way conversation between the switch engines and the Flat Rock yard office. This area was selected for tests of the radio because of the numerous conditions which might interfere with the operation of such a system. For example, there are several steel bridges over the tracks, and many steel buildings near the railroad. Steel reinforced concrete arches, installed years ago to support overhead catenary for electric traction, are spaced 300 ft. apart on ten miles of the line between Flat Rock and Dearborn.

Basically the system is space radio operating at 161.775 mc., frequency modulation. Transmitter-receiver sets were installed at the yard office in Flat Rock and on two locomotives. In order to insure uniform coverage of the more remote area regardless of the adverse conditions, a "satellite"

Emery Lee, F.C.C. inspector, using radio in Flat Rock yard office, while W. S. Halstead, Farnsworth consultant, looks on

station, including a transmitter-receiver set, was installed at Dearborn, 14 miles from Flat Rock, the two stations being connected by 189-kc. carrier current superimposed on previously existing telegraph and telephone wires on the railroad pole line. An extra advantage is that the line wires between the two stations function in inductive carrier operation with the VHF equipment in the fixed stations to tie them together, thus eliminating any blind spots in the space radio operation between the two stations.

An advantage of using the carrier current rather than a physical circuit is the improved audio-frequency characteristics, which may be essentially uniform between 200 and 4,000 cycles or higher, and because of the relative lack of line noise and cross talk, which, with FM carrier equipment in the spectrum between 150 and 200 kilocycles and high signal level, is practically non-existent.

It is interesting to note, although this installation employs the overhead circuits as wave-guiding media, tests have indicated that buried conductors will work effectively if not in lead sheathing over too great a distance, say one to two miles. In locations where lead-sheathed cables are used as the only wayside conductors, no effective induction field exists at lateral distances from the line, although the carrier passes through lead sheath.

Due to the use of the 189-kc. carrier current on the line wires, additional transmitters and receivers may be coupled to the wayside wires at any point, and the same or different carrier frequencies can be employed. The induction link permits use of lightweight walkie-talkie units, or small, camera-size "paging" receivers at any point in the vicinity of the wayside wires.

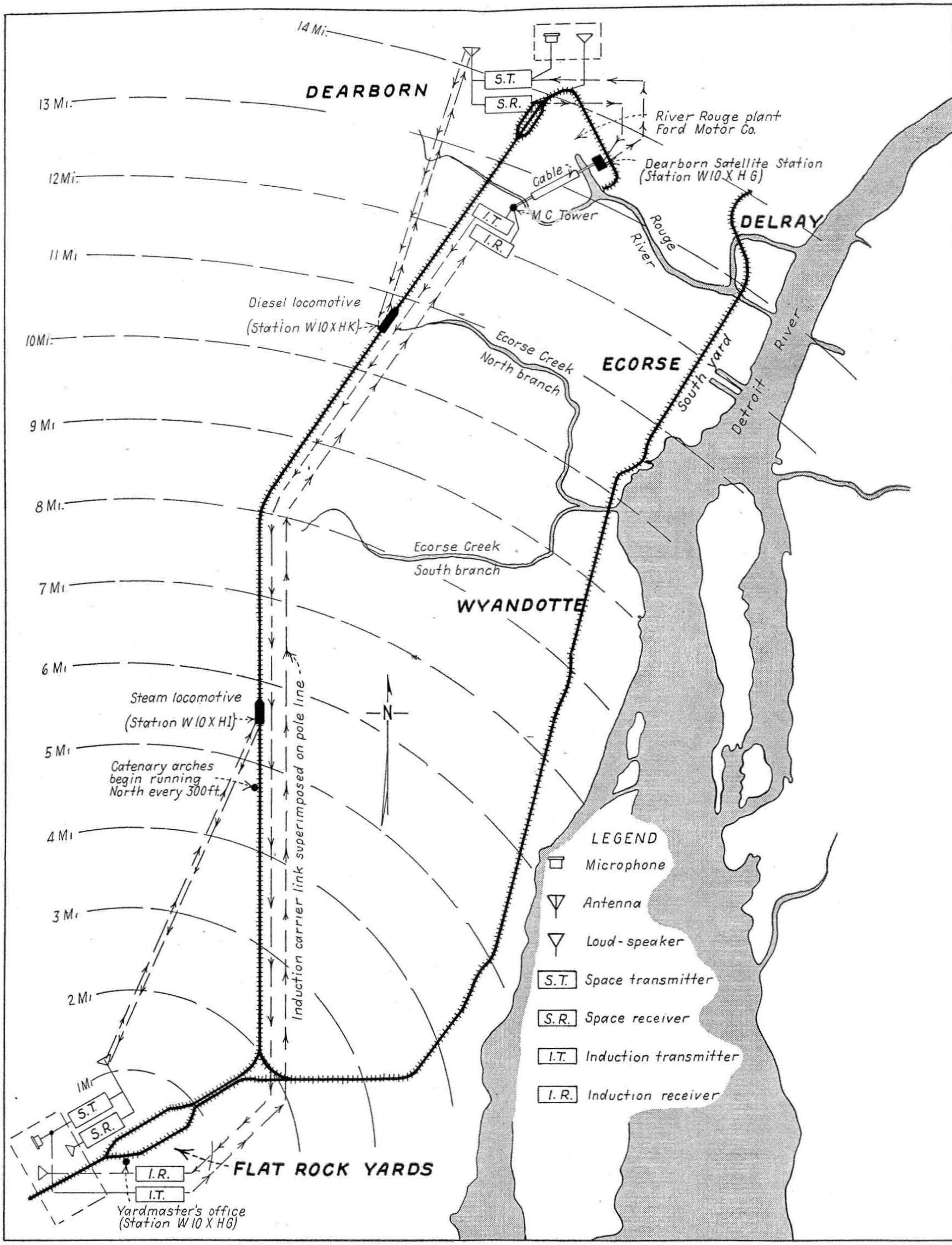
Operating Procedure

The panel of the radio set on the yardmaster's desk at Flat Rock has a small switch which can be turned to either of two positions, "Local" or "Remote." His equipment includes one microphone, and two loud-speakers. If he wants to talk to a locomotive that he knows is working in or near the Flat Rock yard, he throws the "Local" switch which connects his space-radio transmitter-receiver set so that it operates only in connection with the antenna at that office. He then calls the locomotive and carries on conversation with the engineman in the conventional manner.

On the other hand, if the yardmaster at Flat Rock wants to contact a locomotive that is working in the vicinity of Dearborn, Delray or Ecorse, he throws his "Remote" key, which establishes connections so that his microphone and the other loud-speakers function via the induction carrier current superimposed over the line wires between his Flat Rock office and Dearborn, at which point the "satellite" transmitter-receiver equipment operates in connection with the antenna at that location. In this arrangement the carrier on the wires is at the rate of ½ watt at a frequency of 189 kc. The transmitter-receiver set at Dearborn operates at 161.775 mc., frequency-modulation, just the same as the equipment at Flat Rock.

Normally the system as a whole is standing by, so that any calls would come in over the loud-speakers not only in the locomotives but also in the yardmaster's office at Flat Rock. Calls from locomotives working in the yard at Flat Rock would be picked up by the antenna at that office, and be reproduced by one of the loud-speakers in the yardmaster's office. Calls from locomotives in the vicinity of Dearborn and Delray would be picked up by the antenna at the satellite station, and be transmitted by the inductive carrier on the line wires to the office at Flat Rock where they would be reproduced on the second loud-speaker in the yardmaster's office.

Each radio station is assigned call letters by the Federal Communications Commission. The call W1OXHG is used at the central station at Flat



Map of the territory covered in the D.T. & I. radio tests in the Detroit area, showing the complete system used. Diagram shows how yardmaster at Flat Rock communicates directly with the steam locomotive, through the induction carrier link and satellite station to the Diesel locomotive, and how satellite station communicates through satellite transmitter to the Diesel locomotive with the induction link providing the signal to the Flat Rock yardmaster. The Diesel and steam locomotives communicate directly with each other, transmitters being monitored by fixed stations at Flat Rock and Dearborn

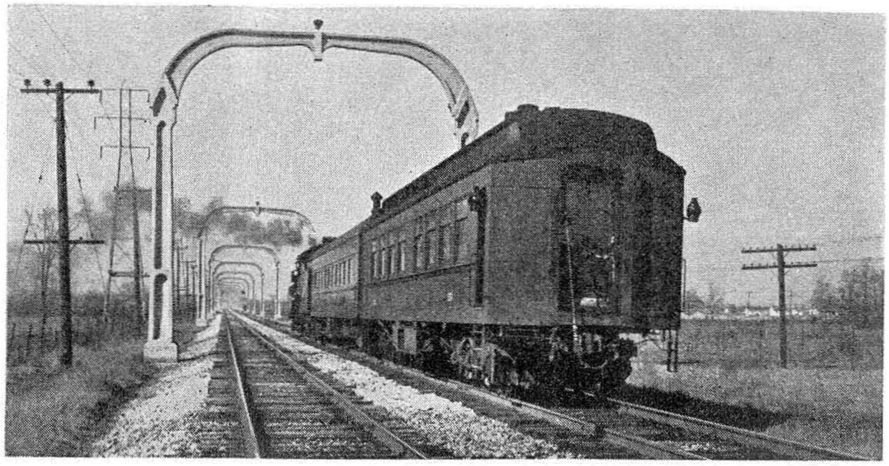
Rock yard, and at the satellite station at Dearborn. The call W1OXHI is used on steam locomotive No. 106, and W1OXHK is used on the Diesel-electric locomotive No. 900. The operation of all radio facilities in the yards is governed by the operating rules and regulations of the Federal Communications Commission.

Test Results Satisfactory

As mentioned previously, there is a section on the double-track main-line between Dearborn and Flat Rock where overhead steel-reinforced concrete arches are spaced every 300 ft. While it was expected that these arches might create "radio shadows," or interfere with reception of radio wave energy, the very high frequency FM transmission and reception at these points was not affected in any manner.

At all points in the Dearborn and Flat Rock areas, during the tests, very strong signals were received on the locomotives and at the fixed stations, with none of the "fringe" conditions, such as "flutter" or unsteady signals being noticeable. In one preliminary test, "solid" two-way communication was maintained up to 29 miles southwest of the Flat Rock stations, and the message could be copied up to 34.5 miles with the "squelch" open. Since the radiation patterns about each fixed station and locomotive were essentially omni-directional, a total area of about 700 square miles was covered by the system.

In another interesting test, one locomotive was moved into a steel-frame locomotive maintenance building at the Ford plant, while the second locomotive was moved between two large steel buildings, with overhead crane structures, at the Murray Body Corporation, in Detroit. Solid two-way communication was maintained from each of these locomotives with Flat Rock 14 miles south, and solid two-way communication was maintained between the locomotives except in one spot under the crane structure. A slight movement of the locomotive resulted in normal signal level being re-established. At the time of this test the air-line distance between the locomotives was approximately 3.5 miles.



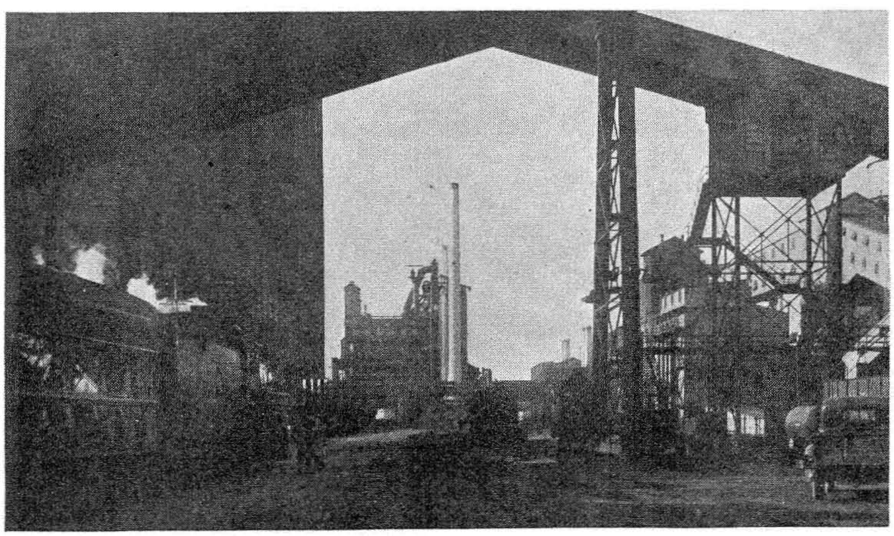
Radio-equipped steam locomotive No. 106 on northboud train in section of double-track territory between Flat Rock and Dearborn where there are concrete arches

Frequency Modulation

After study of all factors involved, the engineers of the Detroit, Toledo & Ironton and the Farnsworth Corporation decided to use frequency-modulation on this project because of several reasons, the first of which was because of the relative lack of heterodyne whistles between carriers of the fixed stations and different mobile ratio units on the same carrier frequency, thereby providing a quiet audio background. Another reason for the decision to use FM equipment is because of the relative lack of objectionable "flutter" in areas of low-signal intensity, due to the very rapid action of the limiter circuit in FM receivers, as contrasted with the relatively slow action of automatic volume control (AVC) circuits in AM radio receivers.

The relatively flat automatic volume control characteristic of an FM receiver, as contrasted with that of AM receivers, is another reason for the type of modulation used. There is a minimum change in audio volume as a mobile unit moves from the immediate vicinity of a fixed station to a remote part of the service area of the station. Frequency modulation, furthermore, was decided upon because the increase in transmitter-output power with a given primary power supply, made possible by the elimination of the high-level modulation of AM radio equipment. This is an important factor on mobile radio units, such as on cabooses and locomotives, where the power supply is limited, especially when transmitters in excess of 10-watt power-output ratings are employed.

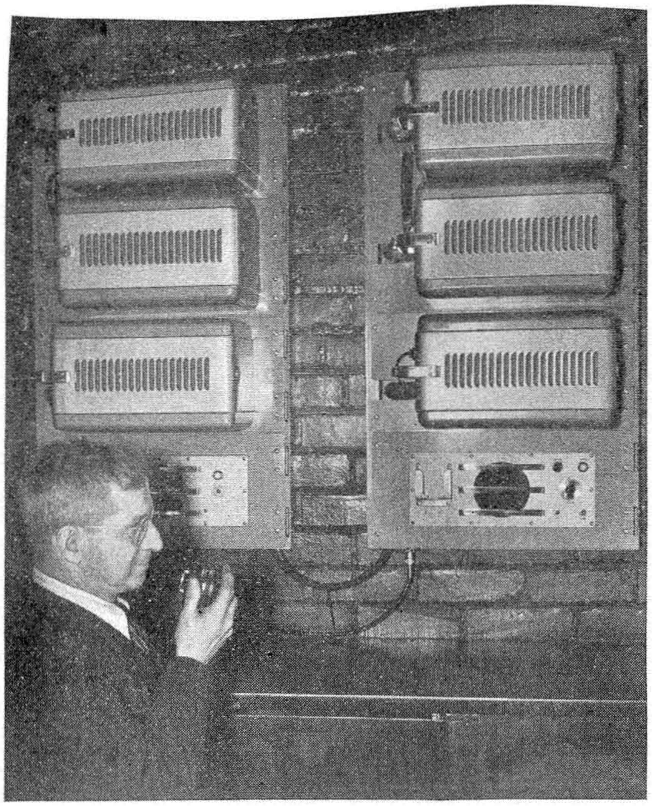
By the use of FM, there is an improved signal-to-noise ratio in "radio shadow" or "fringe" areas. Furthermore, in using FM radio, rather than AM, no additional radio equipment is required on the mobile units or at fixed stations and, in some instances, a smaller power supply unit may be used.



View of Ford River Rouge plant gives a good idea of the industrial area where uninterrupted communication was maintained. Radio-equipped locomotive 106 at left

Radio and Inductive Communications Equipment

The VHF radio and inductive communications equipment employed in this installation was manufactured by the Farnsworth Television & Radio Corporation. The transmitters and receivers for locomotives and fixed stations are interchangeable. The power-output rating of the FM space-radio transmitters is 10 to 15 watts, while



The satellite equipment at Dearborn. While this station operates unattended, it may be used as an originating station if desired

the maximum power output of the inductive transmitters is approximately 35 watts. The receivers of both the space and inductive radio types have an undistorted power output rating of approximately 5 watts. The sensitivity of the VHF receiver is approximately 0.5 microvolts for full saturation of the FM limiter. The sensitivity of the induction radio receiver is approximately 10 microvolts for full saturation of the FM limiter.

The equipment has been designed for dual-frequency operation if desired at a later date. Such operation is advantageous in emergencies when cutting in on radio conversations and also in the event of more locomotives being equipped with radio in the future. Radio channels are 60 kc. wide, and the second channel can be 60 kc. above or below the 161.775 mc. frequency of this installation.

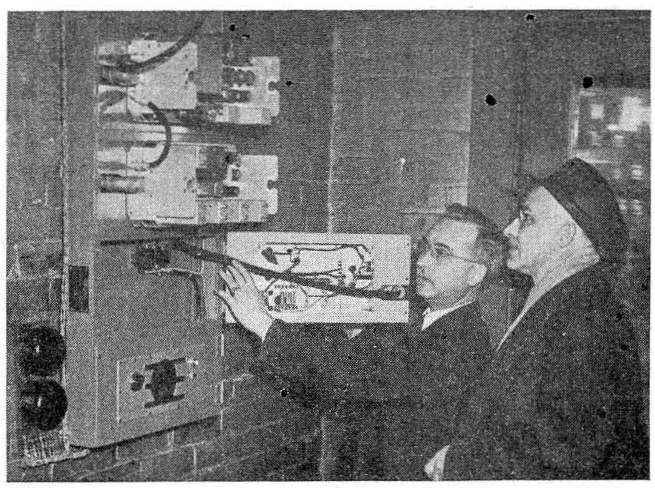
Fixed Station Equipment

The fixed-station equipment in the yardmaster's office at Flat Rock includes transmitter, receiver, power supply and monitoring units, mounted in rack-type installations, in a shanty located at the foot of a large water tower near the yard office. In addition to this equipment, at the same location are the induction radio transmitter and receiver, power supply and monitoring units. In the yardmaster's office is a control unit located on the yardmaster's desk. This equipment is connected to the equipment in the shanty by a standard telephone pair with both the space radiating and induction transmitters and receivers. A push-button marked "test" on the control unit provides a means whereby the integrity of the communications circuits can be checked quickly at any desired time. The loud-speakers are the 5-in. cone type, mounted in the control unit on the wall or desk. Microphones are the noise-reducing dynamic (moving coil) type.

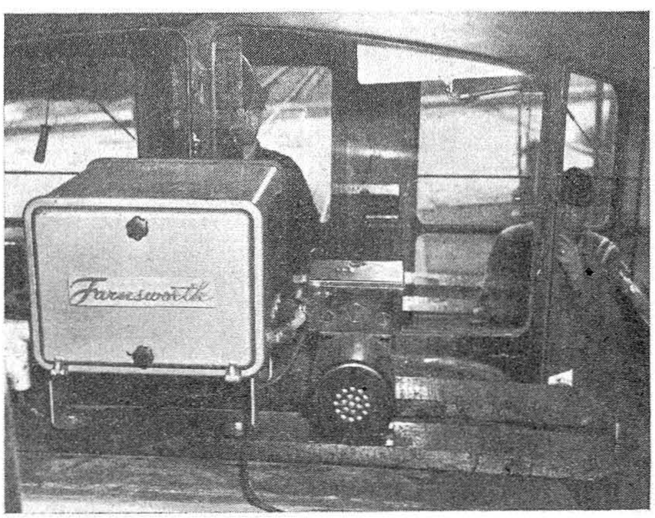
The fixed station antenna is located 160 ft. above ground on top of the water tower, and is connected to the equipment by a coaxial cable. This antenna is an improved type, developed by Farnsworth, which resembles a coaxial antenna in external appearance. It provides a power gain of two-to-one over that of a vertical-dipole type antenna. It is simple in construction, yet advantageous because of the increased gain, and having, at the same time, a circular radiation pattern.

Mobile Equipment

The equipment on the steam locomotive No. 106 includes a transmitter, receiver and power supply unit, located on the top of the tender in air-tight housings. These housings are made of ¼-in. sheet aluminum alloy, and are provided with cast-aluminum doors and ends. Each unit is further individually housed in an aluminum alloy case properly shock mounted from the outer housing. The mobile control unit, located in the cab, is connected with the transmitting and receiving equipment on the tender, by means of a 14-conductor cable in a



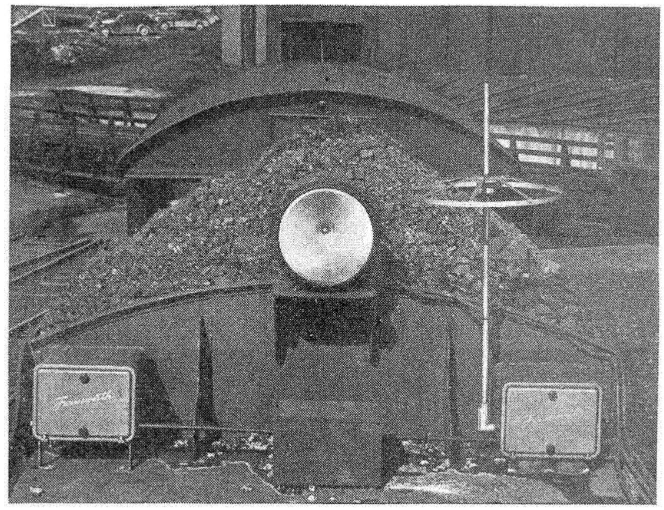
Right — W. G. Clinton, D. T. & I., explains the induction equipment in MC tower to Emery Lee, F. C.C. inspector



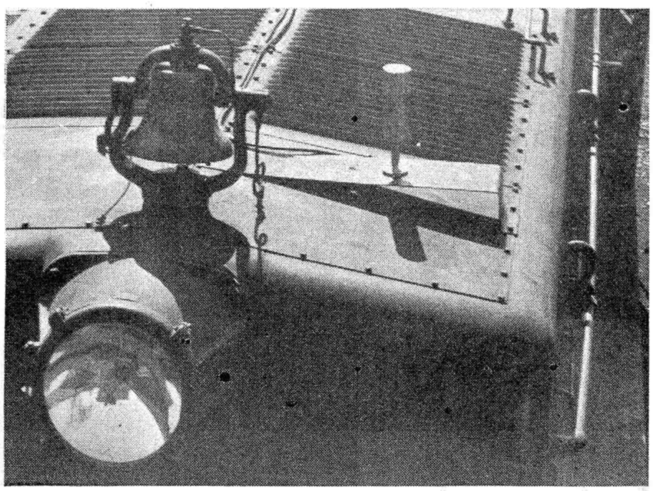
Left — Radio equipment and power - supply unit on the Diesel locomotive No. 900

rubber hose with Crouse-Hinds connectors.

A cartwheel-type ground plane antenna 18 in. high is used on the steam locomotive being mounted on the tender. This antenna is provided with a tuning circuit enclosed in a housing at the center of the ground-plane section. The antenna is connected with the transmitting and receiving installation by coaxial cable of the same type used at the fixed station.



Right — Mounting of radio equipment and antenna on tender of locomotive No. 106



Left — "Firecracker" antenna used on the Diesel - electric locomotive 900

On the Diesel locomotive the transmitter, receiver and power supply unit are mounted outside, over the motor hood, on boards. The antenna on the Diesel locomotive is an experimental type, under development by Farnsworth, having a height of less than 11 in. above the top of the engine hood. Because of its shape and size, it is referred to as the "firecracker" antenna.

Microphones on the locomotives are the sound-reducing dynamic (moving coil) type with a push-to-talk switch, and the locomotive loud-speakers are the weatherproof re-entrant (double-horn) type.

Satellite Station Equipment

The equipment at the satellite station in Dearborn is identical to that of the fixed station at Flat Rock with the exception that there is no remote control unit, the circuits being arranged so that the equipment may be operated locally or automatically without an attendant. This satellite station is on the east side of the Ford plant, and an underground cable extends for about a mile under this plant to the MC tower on the west side. On account of a large capacitance to ground of 1 microfarad on each conductor, it was decided that this condition would cause too much antenuation on the 189 kc. inductive carrier current. Therefore, the inductive equipment was located in the MC tower beyond the west end of the underground cable. The 189 kc. inductive carrier signals from Flat Rock are transformed to audio signals at MC tower before being placed on a pair of wires in the cable, and vice versa.

Power Consumption

The power consumption by the FM transmitting and receiving equipment of both space-radio and inductive types, at fixed and mobile stations is approximately 240 watts when transmitting, 180 watts when standing by, and 140 watts when receiving, using a 115-volt 60-cycle a.c. power supply. With a special 32-volt voltage regulated dynamotor, of relatively-low efficiency (about 40 per cent) the overall power consumption is approximately 450 watts when transmitting, 350 watts when standing by, and 300 watts when the equipment is receiving.

Power Supply Units

The power supply unit on the Diesel locomotive is the dynamotor type operating on 64 volts d.c., from the locomotive storage battery, and which provides the filament and plate voltage. The power supply unit on the steam locomotive includes a rotary converter for operation on 32 volts d.c. from the locomotive headlight generator. This unit supplies 110 volts a.c. to a standard 110-volt a.c. radio power supply unit. Power supply units for fixed stations operate on 115 volts a.c. at 60 cycles.

A light is incorporated in each power unit. In the event of power failure, this light goes out, enabling a maintenance man to ascertain quickly whether power difficulties exist in the equipment.

Frequency Range and Power Output of Equipment

The radio equipment is tunable in the radio band from 152 to 162 megacycles. The exact frequency used is 161.775 mc., as allocated by the Federal Communications Commission. The radio equipment employs quartz-crystal control in both the transmitter and the receiver. Furthermore, provision is made for operation on any two selected frequencies (alternate channels) by means of a selector switch at the control position, and use of two crystals in the transmitter and receiver. Frequency stability is maintained within ± .005 per cent of the assigned carrier frequency in accordance with the rules and regulations of the Federal Communications Commission. This absolute tolerance is an interesting comparison with the figure of .02 per cent required for an aviation transmitter. The power output of the transmitters is 10 to 15 watts, dependent upon loading adjustment. In the test period 10 watts of power was used.

Installation

This installation and the tests were under the jurisdiction of William G. Clinton, signal and communications engineer of the D.T.&I. Mr. Clinton was assisted by H. C. Lorenzen, signal engineer and superintendent of telegraph of the Pere Marquette; M. F. Anderson, communication engineer of the Pere Marquette; and by Joe Gray, head of communications for the Ford Motor Company. The principal items of radio equipment and radio engineering services were furnished by the Farnsworth Television & Radio Corporation.