DOMINION OF CANADA
DEPARTMENT OF MARINE
HON. A. DURANLEAU
Minister
RADIO BRANCH
C. P. EDWARDS, O.B.E., F.I.R.E., A.M.E.I.C., Director

SUPPLEMENT "A"
TO
BULLETIN No. 2

Radio Inductive Interference

By
H. O. Merriman, B.A.Sc., E.E., A.M.E.I.C., Assoc. A.I.E.E., Assoc. I.R.E.,
Engineer-in-Charge, Interference Section.

OTTAWA
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1934

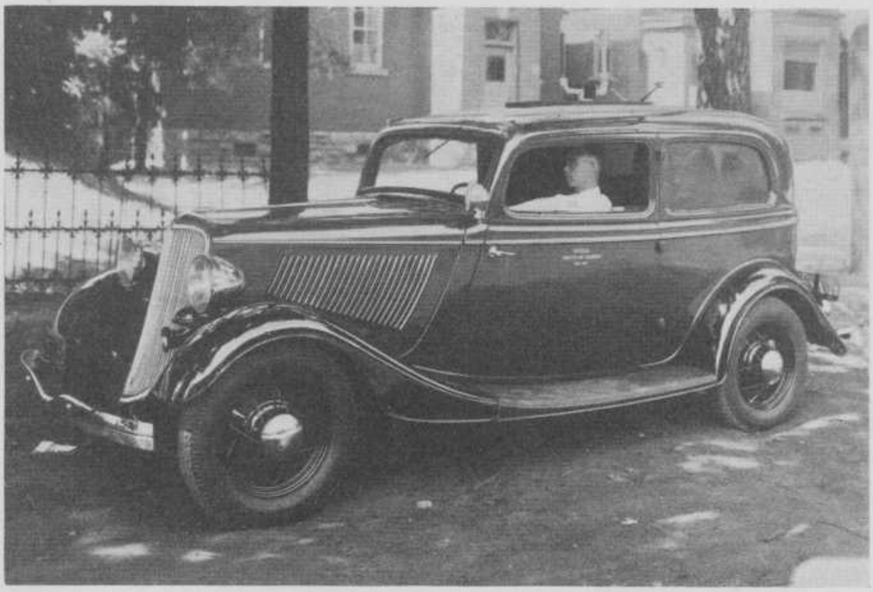

Figure No. 1.—Front View of Car.

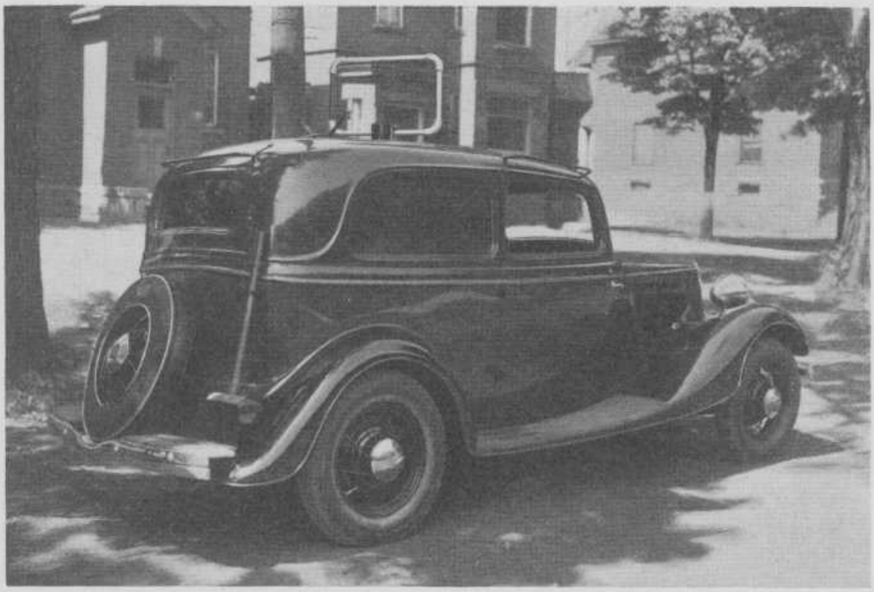

Figure No. 2.—Rear View of Car.

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"Additional copies of this Supplement may be obtained from The King's Printer at 15 cents each. Copies of Bulletin No. 2, Radio Inductive Interference, published January, 1932, may also be obtained at a price of 35 cents each."

PREFACE

SINCE the publication of Bulletin No. 2, in January, 1932, the study of radio interference by the Radio Branch of the Department of Marine has advanced considerably, and our investigation technique and equipment have been materially improved.

This supplement is not intended to be a complete thesis, but should be read in conjunction with Bulletin No. 2 in order that the latest methods of investigation and suppression of interference may be understood.

January, 1934.

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IMPROVED INVESTIGATION EQUIPMENT

Description of Car

A standard, two-door, light coach has been altered as shown in the photographs, Figures 1 and 2, to suit the requirements of interference investigation. The rear side windows have been replaced with steel panels, steps fitted inside the rear bumper at each side of the spare wheel, and grab handles mounted over each door and at the rear of the car. These handles are for the convenience of the lineman or assistant investigator when riding on either running board or the rear steps during investigations of distribution systems. A push button mounted on the rear operates a buzzer inside the car for signalling purposes. A bracket to carry the mallet is also mounted at the rear of the car.

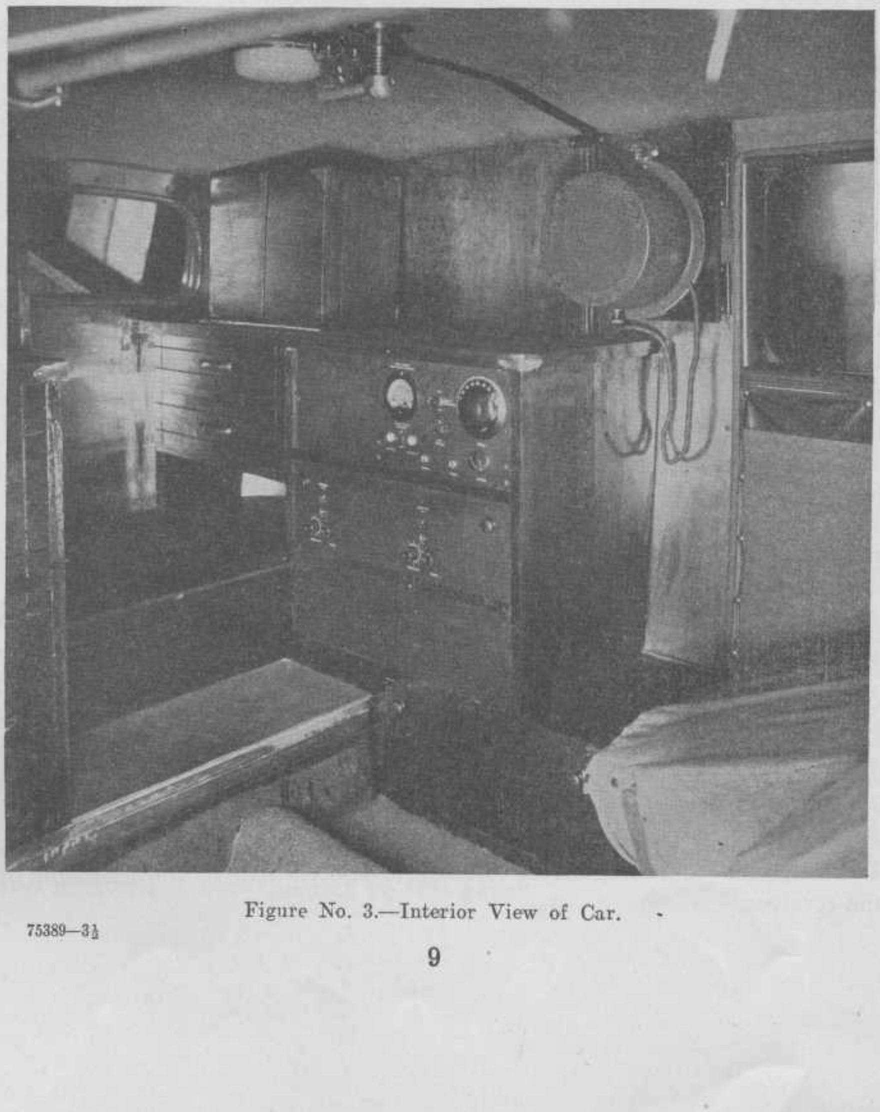

Figure No. 3.—Interior View of Car.

The interior walls of the car, forward to the doors, are lined with three-ply wood, the space between the lining and the walls being filled with insulating material to deaden noise.

Cabinets are permanently installed in the car, as illustrated by the interior photograph, Figure 3.

A spotlight controlled from within the car provides the illumination necessary to inspect outside wiring at night.

Radio Receiving Equipment

The radio receiving equipment is connected as shown in the diagram, Figure 4, and consists of the following:—

Battery

A six volt lead battery, 100 ampere hour capacity, is used for operating the radio equipment and is installed in the lower part of the right hand cabinet. A twin conductor, No. 10 flexible copper, rubber insulated, armoured cable is used to connect the battery to the radio equipment.

"B" Supply

High voltage current for the receivers is supplied by two dynamotors, relay operated from the radio receivers. The dynamotors, with relays and fuses, are located in the lower compartment of the left hand cabinet. Normally, the rear dynamotor feeds the rear receiver and the forward dynamotor the forward receiver, but, as plug and socket connections are used, alternative hookups can be made in the case of failure of individual units.

A few cars are now being fitted with vibrator type "B" supply units in place of the dynamotors described above.

Receivers

The receivers used are standard automobile units which have been converted in the following way:—

A calibrated sensitivity control in the input circuit replaces the standard manual and automatic volume control.

The input circuit of the receiver is altered by disconnecting the standard input coils and the first ganged condenser and substituting an input circuit, as shown in Figure 5, consisting of a special three-winding transformer which is tuned by a variable condenser on the instrument panel. This circuit is connected direct to the grid and cathode of the first tube of the receiver.

The two receivers are mounted on a vertical rack suspended by rubber shock absorbers and are located in the centre compartment at the rear of the driver's seat. A metal panel is mounted in front of these receivers, and the sensitivity and tuning controls are brought to the front.

Loudspeaker

One loudspeaker is used with connections for operation with either of the two receivers and is mounted on hinges on the left inside wall of the car in such a position that it may be hooked back, or swung out through the window of the door to enable the output from the receiver to be heard outside the car. The loudspeaker is provided with a four-position tone control, which, when set for maximum high frequency response, gives an excess of frequencies above 2,000 cycles per second.

Loop Antenna

A tubular frame loop antenna, the direction of which may be controlled by a handle inside the car, is mounted on the roof. The loop may be raised to a vertical position for investigation work and lowered to a horizontal plane for travelling or to clear garage entrances, etc. The frame of the loop is rectangular in shape and is constructed of three sections of three-quarter inch aluminum pipe and one section of fibre tube, the sections being connected by aluminum elbows. The winding of the loop consists of eight turns of No. 18 flexible, copper wire, rubber insulated, wound in two sections of four turns each, in series. The ends of the sections are brought out to four binding posts in the car.

Aerial

The galvanized wire netting strengthener in the roof of the car, insulated from the metal of the car, is used as an aerial, and a lead from it is brought to the instrument board.

Car Ground

The metal of the car, all parts of which are thoroughly bonded, is connected by flexible, insulated, copper wire to the instrument panel to form a counterpoise for the radio receivers. All the radio receiving circuits are insulated from the frame of the car except at this one connection on the instrument panel.

Instrument Panel

An output voltmeter is mounted on the instrument panel. The tuning condenser, with the necessary switches to control the input to either of the two receivers, is also mounted on this panel.

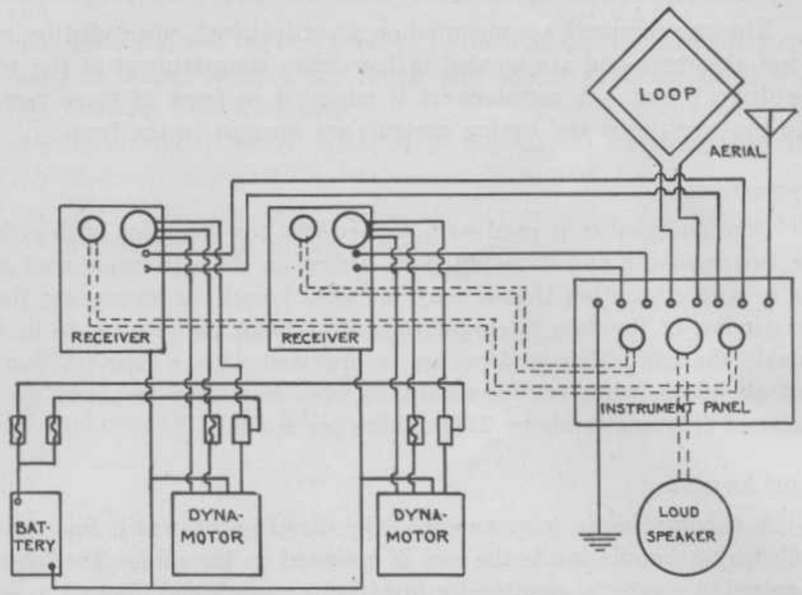

Fig. No.4 — Car Wiring Diagram.

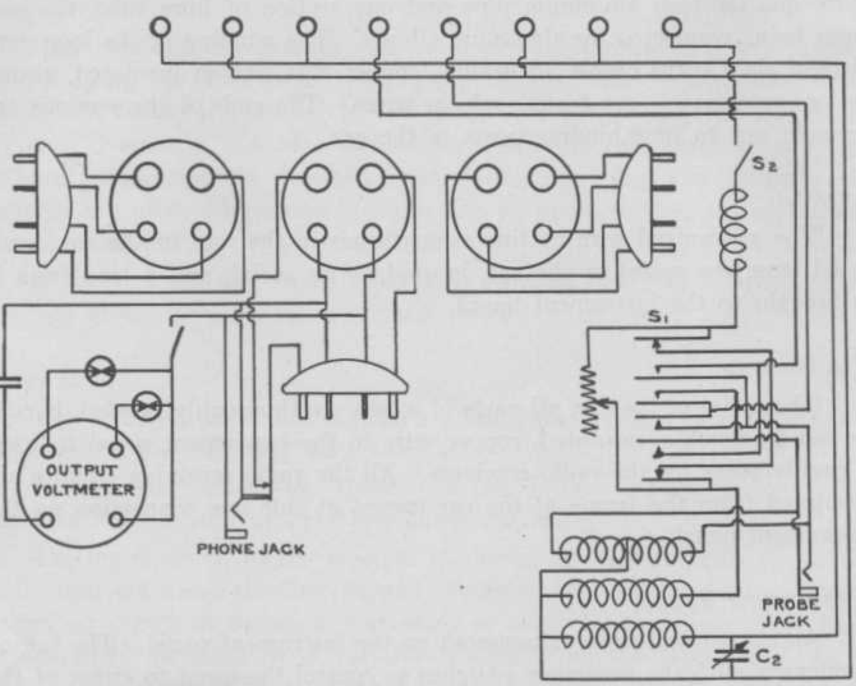

Fig. No. 5 — Instrument Panel Wiring Diagram.

Output Meter

The output voltmeter is of the type employing a moving coil element in a permanent magnetic field and is used in conjunction with a copper oxide, full wave rectifier, connected to multiplying resistances to give three ranges: 0 to 1·5, 0 to 15, and 0 to 150 volts.

The output voltmeter, which has a resistance of 1,000 ohms per volt, is connected to the output of the receiver through one condenser of 2 mf. capacity, and an on-off switch normally connecting for the 150 volt scale. Two spring push buttons mounted in the panel are used to short-circuit part of the multiplying resistance and cause the voltmeter to read on the 15 volt or 1·5 volt scale, as required. This arrangement of push buttons for altering the scale is used to avoid the possibility of damage, which might result from excessive output if the meter is left connected to the low voltage range.

Tuning Condenser

The tuning condenser, C_2, is connected across the input of the radio receiver as shown in the diagram, Figure 5. A log of relative settings of this tuning condenser and the tuning dial of the receiver facilitates operation.

Receiver Input Circuits

Direction Finding

In order to utilize the direction finding characteristics of the loop and antenna, standard practice has been followed by combining vertical and loop reception.

Input Switches

Two switches are mounted in the centre of the panel, the upper one S_1, being a three-position switch controlling loop circuit, the lower, S_2, an on-off switch controlling aerial or vertical circuit. Four different input circuits may be connected to the receiver, as follows:—

(1) Vertical Reception;
(2) Loop Reception (Figure of Eight);
(3) Heart-shaped Reception (Sense);
(4) Probe Reception.

(1) Vertical Reception

The term "direct" or "vertical" refers to reception from an ordinary aerial which has no directive properties. In other words signals of equal field strength, from different directions, will give equal response from the loudspeaker. Such reception may be illustrated by a circle whose radius represents the output volts, as shown in Figure 6.

This type of reception is obtained by throwing the switch S_2, marked "vertical" to the "on" position and the loop switch, S_1, to the "off" position.

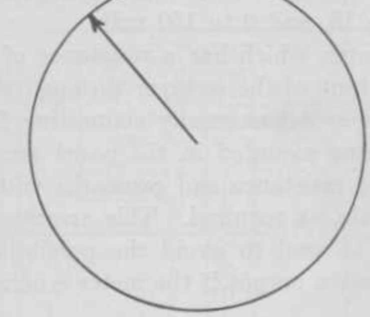

Figure No. 6.—Circle Diagram.

It is advisable to conduct the preliminary patrol of the district with this input to the radio receiver. It will be seen from the wiring diagram, Figure 5, that, with the upper switch, S_1 in the central position, the loop is disconnected from the receiver and the aerial phasing resistance is short-circuited to give the maximum effect of aerial reception.

(2) Loop Reception (Figure of Eight)

The term "loop" or "figure of eight" refers to reception on a closed loop of wire which may be of one or more turns. Its characteristic is such that when the plane of the loop points towards the source maximum reception occurs, and when it is turned through 90°, to position at right angles from the direction of the source, minimum reception occurs. Such reception enables one to determine, for example, that the source is east *and* west, but does not determine whether it is east *or* west.

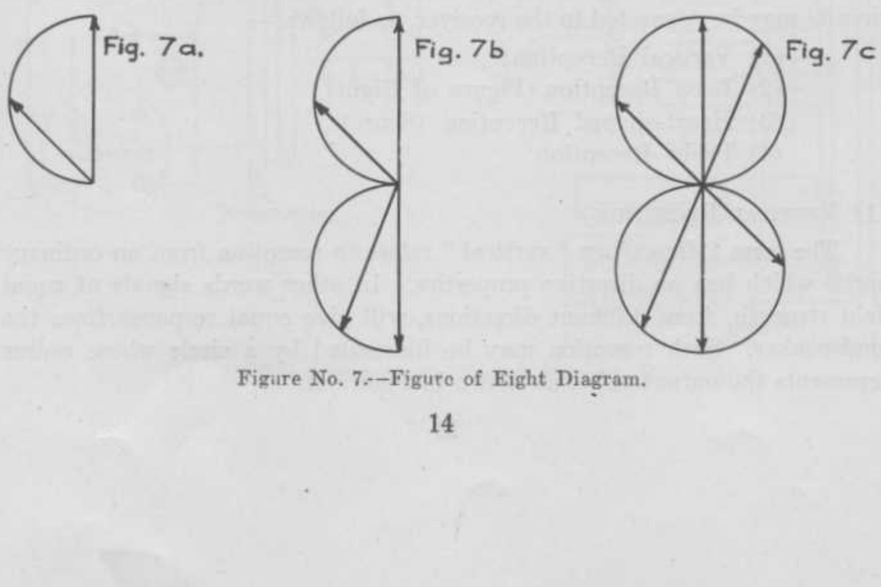

Figure No. 7.—Figure of Eight Diagram.

This type of reception can also be represented by a figure in which the length of a straight line represents output volts and the direction of the line represents the relative direction of the source to the plane of the loop.

Figure 7-a shows the results of plotting the strength of received signals on a line rotated from a position where the source is in the plane of the loop giving maximum reception, through various angles, to a position where the source is at right angles to the plane of the loop giving minimum reception. When the various positions of the outer end of this line are joined a semi-circle is formed.

As the loop passes through the 90° position, it will be seen that the side of the loop which was originally nearer to the source is now farther away. This causes a reversal of phase of the current in the loop, so that the increase in signal strength as the plane of the loop again approaches the position of maximum reception must now be shown diagrammatically by a semi-circle under the other, as shown in Figure 7-b.

By continuing the rotation of the line back to the starting point, a complete " figure of eight " is described by the outer extremity of the line, as shown in Figure 7-c.

This type of reception is obtained by placing the " vertical " switch in the " off " position and the " loop " switch in either the " heart direct " or " heart reversed " positions. The terms " heart direct " and " heart reversed" apply to sense reception.

(3) Heart-shaped Reception (Sense)

The term " heart-shaped reception " or " sense " is applied to the combination of vertical and loop reception. By properly combining vertical reception and loop reception, by means of a special transformer, so that the vertical reception is in phase with one circle of the " figure of eight " diagram and 180° out of phase with the other circle, loud signals are heard from one direction and very weak signals from the opposite direction, with gradually decreasing signal strength in between, as shown in Figure 8.

For the best results, maximum loop reception should equal vertical reception. This will cause maximum sense to be double either loop maximum or vertical reception, and minimum sense to be zero.

As it is difficult to get good " sense " throughout the broadcast band without additional variable controls, the car equipment has been designed for best results at 730 kc. but good results are obtainable from 600 kc. to 900 kc.

It will be realized that " sense " now enables one to determine, for example, whether the source is east *or* west of the receiving point, which was impossible with loop only.

The terms "heart direct" and "heart reversed" refer to the direction in which the handle of the loop points when the loudest signal is being received. If the loop switch is in the "heart direct" position for maximum signal the handle of the loop points towards the source. If it is in "heart reversed" position for maximum signal the handle points away from the source.

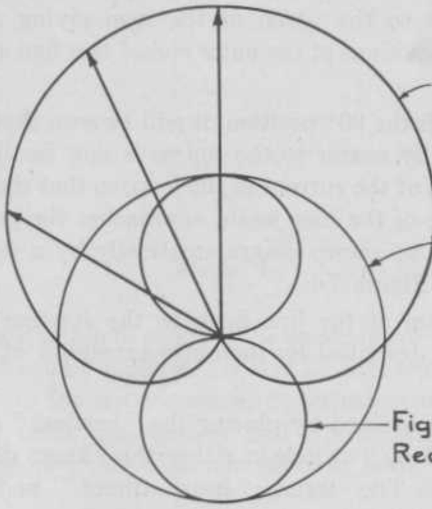

Figure No. 8.—Heart-shaped Diagram.

The manipulation of the various controls to obtain sense is somewhat more difficult than loop reception which only involves turning the loop in addition to tuning the loop circuit and receiver circuits. The simplest procedure is as follows:—

(*a*) Tune in the signal desired, using the vertical aerial with loop off.

(*b*) Switch vertical aerial off and loop on and, while swinging the loop, adjust the tuning on the control panel slightly below that for vertical reception; the tuning of the receiver proper does not need to be altered. Then set loop at the position where maximum reception occurs. Adjust volume to a reasonable level well below the saturation point of the receiver.

(*c*) Switch on the vertical aerial and retune for maximum signal, using the condenser on the control panel only.

(*d*) With the loop switch on the "heart direct" side turn the phasing resistor through its full range and observe if any change is made in the signal strength. If not, switch the loop to the "heart reversed" position and repeat. It will be observed that, on either the "heart direct" or "heart reversed" position of the loop the phasing resistance reduces the signal considerably for some particular setting of the resistance. This is the correct position for sense reception. When the loop switch is now changed to the opposite position loud signals will be heard, and, by noting the direction in which the loop handle points, the absolute direction of the source can be observed. If there is doubt about the correctness of the sense indication a check can be made on a broadcasting station whose location is known.

(4) Probe Reception

The neutralized probe may be connected to the receiver by placing the loop switch in the " loop off " position and the vertical switch in the " vertical off " position, and connecting the plug on the twisted pair from the probe in the jack marked " probe." The tuning condenser on the instrument board should be adjusted to give maximum response with the probe for any given frequency setting of the receiver. The technique in connection with the use of the probe is given elsewhere.

Use of Sense Finding Equipment

Wavefront of Radiation from Power Lines

The wavefront of radiation close to power wires, as a general rule, progresses from the source in a plane perpendicular to the power wire. This condition exists where the surge originates at a single point and is conducted along a line free from discontinuities for a considerable distance, and where the magnitude of any reflected wave is small compared with that of the original wave.

Location of Faults on High Tension Lines

The sense finding equipment is of great value where the line is paralleled for its entire length by highways; faults giving rise to radio interference may be located at normal touring speed, since the equipment indicates reversal of sense immediately the fault is passed en route.

It is also of value in locating line faults occurring at points on the system inaccessible to the radio interference patrol car. Where a line deviates through rough country, over marshes and wooded territory and comes close to the patrol route or crosses it only at interval points, sense readings taken at these points will show the particular section of line in which the interference source is included.

This is illustrated in Figure 9 where a piece of wire thrown on one phase of the high tension line at the point " x " caused considerable radio interference for several miles along the system. The arrows represent the sense finder indication at two points where the line intersects the patrol route and clearly indicate the section of line to be given detail inspection. Without sense finding equipment much difficulty is usually experienced in isolating the particular line section responsible for interference; in this and similar cases, isolation by the intensity method alone would involve a considerably greater amount of patrol work, much of it on foot with portable receiving apparatus.

The sense feature is advantageous in the investigation of intermittent faults and defects which give rise to interference of continuously varying intensity. Single bursts of interference for instance, occurring at irregular intervals, present a difficult problem inasmuch as the duration of the noise is not sufficiently long to permit location by patrol for the point of maximum intensity. Sense readings, however, may be taken in the space of a few seconds, and from indications at various points on the line it is possible to work progressively closer to the source until its exact location is established.

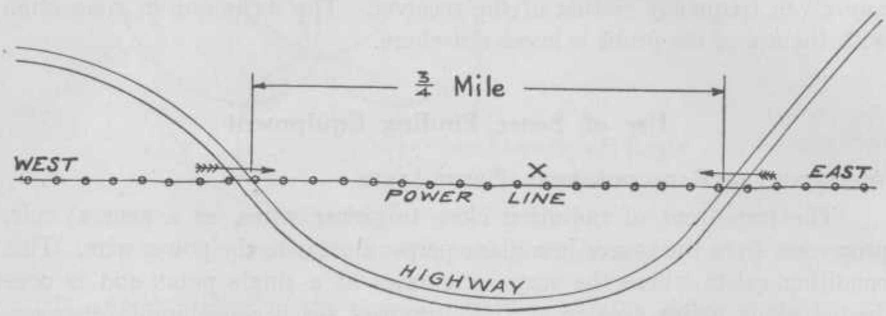

Figure No. 9.—Illustration of the Use of Sense Reception.

In the case of interference which varies continuously in intensity as a result of rapid changes at the source, patrol for the point of maximum radiation is difficult. So long as the noise is active, however, sense readings can be obtained regardless of the intensity value and the source located by the procedure adopted in the case of intermittent sources.

Distortion of Wavefront

The direction of radiation from a power line is distorted by discontinuities of the conductor, transpositions, sharp turns and taps. Dead ends, and changes in the electrical characteristics of the line such as terminals between cable and overhead line, are apt to cause a reflection of the surge and thus considerably distort the wavefront. This condition may also be noted in close proximity to wiring networks. Where the reflected wave is of the same order of intensity as the original wave, standing surges may occur on the power line which will prevent the sense finder giving a clue as to the absolute direction of the source. Where interference surges on a high tension line are distributed more or less uniformly along the line, as in the case of normal "high tension fry," or, where similar surges originate on the line at both sides of the point under investigation, the direction finder will not indicate absolute direction or sense.

Limitations of Use of Sense Finder

In a network of wires it frequently happens that false indications are given by the sense finding equipment. The interfering surge divides between the conductors of a network inversely according to the impedance of each circuit. The sense finding receiver may be located near a conductor which is carrying the surge in a different direction to the most direct air line from the source, as illustrated by the following example:—

Sense Finding from Passing Street Car.—The interference car was parked under a feeder at the side of the road while the trolley line in the centre of the road about 30 feet from the feeder was tied into the feeder at a point 50 yards in front of the interference car and, also, 500 yards behind the interference car. The sense finding equipment indicated a forward sense from a passing street car until it reached a point about 200 yards in the rear. The radio sense finder then showed a reversal of sense. This would indicate that the surge from the street car, when opposite the radio car, reached the radio receiver by way of the tie-in from trolley to feeder fifty yards in front of the interference car and then via the feeder, thus, indicating a forward sense. The reversal of sense did not occur until the surge reached the interference car along the feeder from behind.

Reverse sense indication is sometimes caused by the surge travelling along a power line with comparatively low radiation until it reaches a network of wiring or dead end favourable to greater radiation. If the interference car is near this network of wiring a stronger signal will be picked up from this radiating network than from the power line carrying the surge.

Magnetic Field of the Power Line

The sense finding equipment will not operate satisfactorily if the loop is so close to the power wire that it will be greatly influenced by the magnetic field of the surge. Under this condition the strength of the loop reception will be excessive preventing the necessary balance and correct phase relation between loop and aerial reception required to give sense.

Use of Neutralized Probe

New test methods have been evolved, and new apparatus developed which supersedes the shielded probe antenna formerly in use.

Description of Apparatus

The complete neutralized probe is indicated by the diagram, Figure 10.

(*a*) *Portable Antenna.*—A light, portable cage antenna which may be carried at the end of a 10 or 15 foot rod is used as a pick-up for broadcast signals or interference of intensity less than 1 millivolt per metre. This should not be used in close proximity to power lines.

(*b*) *Potential Probe and Line.*—A short probe antenna, 3 inches long, an antenna transformer and radio frequency transmission line are made in one unit and insulated for use in probing moderate and low voltage electric conductors.

Warning.—Although this probe and transmission line are insulated to withstand, on test, a voltage of 20,000 volts, the investigator should consider the equipment a bare conductor as far as any danger to life is concerned. The apparatus may be used for the purpose of probing conductors up to 5,000 volts but the investigator must always stand clear of all equipment connected to the probe and use a receiver with loud speaker. HEAD 'PHONES MUST NEVER BE USED IN CONJUNCTION WITH THE PROBE ANTENNA.

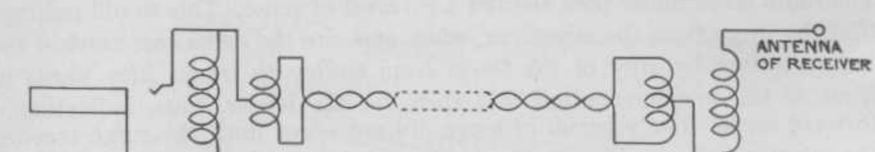

Figure No. 10.—Wiring Diagram of Neutralized Probe.

(*c*) *Set Transformer.*—The radio transmission line is connected to the primary of the special transformer; the secondary of the transformer is connected to the aerial and ground of the receiver by appropriately marked leads which should be kept short. A variable condenser of approximately 0·0005 mf. is connected between aerial and ground terminals in order to tune the input to the same frequency as that of the receiver. These condenser leads should also be kept as short as possible.

(*d*) *Removable R. F. Coil.*—A removable coil of five turns is connected to a special two conductor plug which may be inserted in the end of the potential probe to connect this coil across the primary of the probe transformer. The probe with this R.F. coil connected is converted from a potential probe to a current probe. The current probe indicates the presence of a radio frequency magnetic field and when placed parallel to a conductor will indicate the presence of an R. F. current. The presence of an R. F.

current is indicated by the Figure of Eight direction finding diagram obtained by turning the coil from a position parallel to the conductor for maximum response, to a position at right angles to the conductor for minimum response. The current probe is not perfectly balanced electrostatically and may be slightly affected by R. F. potential, but the sensitivity of the receiver can be reduced until there is very little pick-up when current probe is held at right angles to a conductor.

(*e*) *Reel.*—The one hundred feet of twisted pair transmission line is coiled on the reel with the inside end brought out for connection to the receiver in such a way that only the desired length need be uncoiled.

Principle of Neutralized Radio Transmission Line

All pick-up by this transmission line itself is neutralized by the centre tap of the transformers, shown in Figure 10. When this system is connected to a receiver there will be no transfer to the radio receiver of signals or interference pick-up by the transmission line.

Any current resulting from pick-up of the transmission line will cause an equal and opposite magnetic field in the primary of the set transformer, and, therefore will not induce potential in the secondary connected to the input of the radio receiver. The signal from the antenna will, however, be transmitted to the receiver by coupling in the antenna transformer, transmission through the line and coupling in the set transformer.

The transformers are designed and constructed to ensure electrostatic as well as electromagnetic balance with regard to the centre tap and must be symmetrical in every way; the centre tapped coil is single layer wound and the outer coil duo-laterally wound. The number of turns in the primary and secondary of each transformer is such that their impedances are properly matched with that of the aerial and input circuit of the receiver, in order to transmit signals at frequencies within the broadcast band with minimum loss. The number of turns in the standard equipment is as follows:—

Aerial primary coil—duo-lateral—200 turns;
Aerial secondary—single layer wound centre tapped—30+30=60 turns;
Set primary coil—single layer wound centre tapped—30+30=60 turns;
Set secondary-duo-lateral—125 turns;
Single layer coils wound on cylinders ⅝″ diameter;
Two layers friction tape between primary and secondary; wire used number 30 silk covered.

USE OF POTENTIAL PROBE

The probe antenna is used for the investigation of interfering surges on power lines. When the probe is placed in close proximity to a conductor the radio receiver will give an indication of the intensity of the surge. Surges on other conductors near the probe transmission line will not interfere with the test. By this method, it is possible to determine which one of a number of wires in close proximity radiates the interfering surge with the greatest intensity.

Use of Current Probe

With the R.F. coil connected to the probe to form a current probe the conductors carrying the greatest R.F. current may be determined. This method is particularly useful in locating defective lightning arresters or other faults producing considerable R.F. current. The ground wire of defective lightning arresters carries considerable R.F. interfering current but the R.F. potential to ground on this wire is low, particularly when the impedance of the ground connection is low. The ground wire of the defective lightning arrester will, therefore, give very little indication with the potential probe but will give considerable indication with the current probe, which will also show a decided Figure of Eight diagram when the coil is rotated with regard to the ground wire.

Exploring Reception and Interference Signals Where Intensity is Less Than 1 Millivolt per Metre

This system can be used for the purpose of making a survey of reception conditions both with regard to intensity of interference and strength of received signal.

In order to increase the overall sensitivity of the installation an antenna is connected to the three-inch probe antenna. This is done by using the lower terminal only of a special plug connected through the end of the insulation of the probe.

It is usually found that the intensity of interference does not increase greatly with height and, therefore, a higher antenna will give a better ratio of signal to noise.

Investigations may be carried out for the following purposes:—

1. To determine the interference field surrounding power lines at distances more than 10 feet from the power lines;
2. To determine the relative intensity of radio signals and survey the radio shadow effects from steel buildings, etc.;
3. To make a radio survey of a property for the purpose of determining the position of an aerial to give the best ratio of signal strength to interference.

AERIAL SYSTEMS

The Importance of Efficient Aerial Installation

An efficient aerial system is an important factor in obtaining satisfactory results from a radio receiver, as it is essential that maximum signal voltage be delivered to the input of the receiver.

This factor is often neglected even by the radio trade, and a wire, suspended from any convenient point without regard to elevation, proximity to electric lines, or shielding effect of metal copings or buildings, is frequently used as an aerial. Consequently, the poor reception obtained from an antenna of this type is blamed on inductive interference when a properly installed aerial system would have ensured good signal strength with minimum pick-up of interference.

Interfering surges travel from their source along conductors and cause a field of inductive influence to surround these conductors. This field of inductive influence varies in intensity and extent, depending on the class of service with which the conductors are associated. The inductive influence extends about 10 feet from house lighting wires, 50 to 100 feet from street car feeders and distribution primaries, and 200 or 300 from high voltage power lines. If a radio receiver and all associated wiring could be located clear of such fields of inductive influence the installation would not be affected by interference. Similar results may be more easily obtained by placing the aerial only in a location outside the field of influence and connecting it to the receiver by a special R.F. transmission line. If the receiver and transmission line are so constructed that they are not affected by interference they may be placed wherever convenient, regardless of the field of influence from power wires.

Position of Aerial

The aerial should be located in such a position that the ratio of signal to interference is maximum. All connections on the aerial should be thoroughly soldered to avoid noises due to corroded or loose contacts.

The following are extracts from the Canadian Electrical Code, Part I:—

"Rule 3701 (i).—Antennae, counterpoises and lead-in conductors outside the buildings shall not be erected at any point where they would cross over or under electric light or power circuits of more than six hundred volts."

"Rule 3702 (*d*).—Antennae, counterpoises and lead-in conductors, where placed so as to cross over or under communication circuits, or power or lighting circuits of less than six hundred volts, shall be so located as to prevent accidental contact with such circuits by sagging or swinging, and the minimum clearance shall be four feet."

The aerial should not be run over property without the owner's permission. This refers, also, to public property such as streets and lanes. Some municipalities will not allow aerials to be run over any thoroughfare. No aerial should be attached to a pole of a public utility without permission.

The aerial should be placed as high as conveniently possible for the double purpose of

(*a*) increasing signal strength, and
(*b*) reducing interference pick-up.

(*a*) Signal voltage at the receiver terminals is materially increased as the height of the aerial is increased. The position of the aerial should be selected to avoid radio shadows which are caused by the shielding effect of grounded metal, such as metal eaves of buildings or metal structures.

(*b*) It is found that the field of interference from power lines is considerably less at a given distance above the power wire than at the same distance to the side and below the power wire. Where possible, the radio receiving aerial should be ten feet or more above any nearby power or lighting wires.

Ratio of Signal to Interference

Maximum ratio of signal to interference is specified rather than high signal level or low interference level considered separately. For example, if it were possible to increase the signal voltage at the aerial terminal of the receiver without increasing the noise level improved reception could be obtained by reducing the volume. If the signal voltage could be reduced slightly, at the same time reducing the noise level considerably, improved reception could be obtained by increasing the sensitivity of the set at the volume control. In either case the net result would be a reduction in noise from the loud speaker with equal volume of the desired program. Practically all modern receivers have excess sensitivity which will allow for this adjustment of the volume control.

No Pick-up Except on Aerial

The receiver should be of a shielded type that will pick up neither signal nor noise with the aerial and ground disconnected and the volume control in normal operating position.

The lead-in connecting the antenna and receiver should be located in a position free from interference. If this is not feasible a radio transmission line should be used.

Types of Aerials

The best type of aerial, as well as its position, should be given consideration, to ensure the maximum ratio of signal to interference. Aerials may be considered in two general classes:—

(1) Horizontal aerial, and

(2) Concentrated aerial.

Horizontal Aerial

The horizontal aerial, as a general rule, will provide greater signal pick-up than a concentrated aerial, although a concentrated aerial will usually provide sufficient pick-up when used with a transmission system having correctly designed transformers at both ends, as the losses are small. In cities, therefore, it is frequently found that the concentrated aerial is more suitable as it is possible to choose a location in the limited space available where the ratio of signal to noise is maximum, while a horizontal aerial may penetrate a field of greater inductive interference. In country and suburban districts where it is possible to run a horizontal aerial free from all electric lines it will probably be better to do so.

Concentrated Aerials

A concentrated aerial should be mounted on a mast from ten to forty feet high on the roof of the building; a height of ten feet is considered sufficient on a residence where the interference field is not intense, while a height of from thirty to forty feet is recommended on the roof of an apartment house, or in industrial districts where there is an intense field of interference.

An iron pipe or a wooden mast with lightning conductor should be used, and properly grounded. The sheath of the transmission line when thoroughly grounded outside the building may be used as a lightning ground if a heavier ground is not available.

The following types of concentrated aerials are recommended where it is considered inadvisable to run a horizontal aerial:—

(*a*) *Umbrella Type.*—The Umbrella Type uses the top sections of a number of guys as an aerial. In this case, the mast should be securely supported by three or more guys and insulators cut in at the top and part way down the guys. These insulators should be of low capacity type or two insulators separated from each other by tarred marline or other weatherproof insulating material. The sections of guys between the insulators should be between 5 and 20 feet in length and bonded together to form the Umbrella Type Aerial. The length of the aerial between insulators will depend on the interference field in the locality.

(*b*) *Basket Aerial.*—A Basket Aerial may be used, consisting of 20 to 100 feet of wire, in any concentrated form, covering an area of from 2 to 10 square feet. When using the basket type of aerial it is essential that wherever aerial wires come in contact they should be soldered. One form of this basket aerial may be referred to as the double diamond, consisting

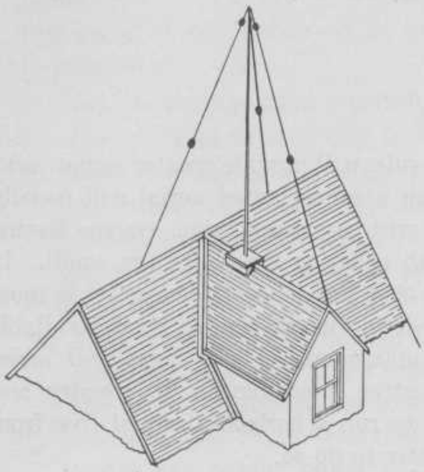

Figure No. 11.—Umbrella Type Aerial.

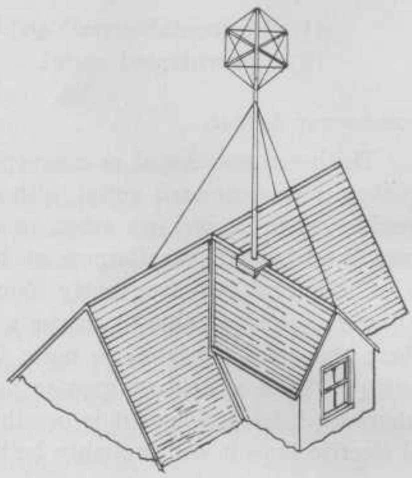

Figure No. 12.—Basket Type Aerial.

of an upright about 5 feet long having two cross arms about 4 feet long at right angles. The top and bottom of this upright are connected to each of the four extremities of the cross arms and a horizontal wire is connected to the extremities of each of the cross arms, thus forming an enclosed cage.

(*c*) *A Sphere.*—A Sphere, or combination of spheres may be used. Many people prefer this type of aerial on account of its appearance. The spheres, however, do not materially increase its efficiency.

(*d*) *Vertical Aerial.* — An ordinary bare or insulated wire 10 or 15 feet long will give approximately equal pick-up to a similarly situated five-foot basket type aerial.

Lead-in or Radio Transmission Line

Lead-in conductors will be considered under the following headings:—

(1) Ordinary Lead-in, Unshielded;
(2) Shielded Lead-in,
  (*a*) Ordinary Shielded Lead-in,
  (*b*) Radio Transmission Line with Shielded Lead-in and Transformers;
(3) Neutralized Lead-in.

(1) Ordinary Lead-in, Unshielded

In locations where radio interference from the house lighting wiring and nearby power wires is not severe the ordinary unshielded lead-in may be used in conjunction with either horizontal or concentrated antenna. Care should be taken, however, with the installation of this lead-in, to avoid undue loss of signal. The lead-in should be considered as part of the aerial and should not be run in close proximity to any house lighting wires. If possible, a space of over six feet should be maintained between the aerial and any parallel wiring and not less than six inches where the aerial crosses any wires at right angles.

The lead-in should run as directly as possible from the aerial to the receiver but should not be run parallel to a nearby water pipe or other grounded conductor which would cause a loss of signal strength. A considerable length of lead-in, in the basement, also tends to reduce signal strength at the receiver. All connections of the aerial and lead-in should be soldered.

There are two distinct methods of preventing the pick-up of the lead-in influencing the radio receiver, i.e. shielding and neutralizing, and there are various ways of applying these methods to radio transmission lines.

(2) (*a*) Ordinary Shielded Lead-in

In this case the aerial is connected to the central conductor of the lead-in and, at the lower end, is connected to the receiver aerial terminal. The shield, consisting of copper wire braid or other metallic tubing, is connected to the ground terminal of the receiver. This shield may be grounded at several points, one of which should be outside the building to provide protection against lightning. The shielded lead-in has the disadvantage, however, of reducing the strength of the desired signal. This loss of signal is caused by the electrostatic capacity, between the lead-in conductor and the shield, which by-passes the radio signal. The use of the shielded lead-in, therefore, usually renders it necessary to increase the sensitivity of the set by adjustment of the volume control. Unless conditions are favourable for the use of the ordinary shielded lead-in it is apt to do more harm than good, as increased sensitivity of the set will tend to increase the noise from the loud speaker.

(2) (*b*) Radio Transmission Line with Shielded Lead-in and Transformers

There are several special aerial systems on the market using transformers and shielded leads-in, the principal parts of which are as follows:—

(i) Aerial Transformer (Step-down transformer connecting aerial to transmission line;

(ii) Shielded lead-in;
(iii) Set Transformer (Optional) (step-up transformer connecting from transmission line to receiver).

(i) *Aerial Transformer.*—The aerial transformer has its primary connected from aerial to ground or from aerial to counterpoise, and its secondary connected to the radio transmission line.

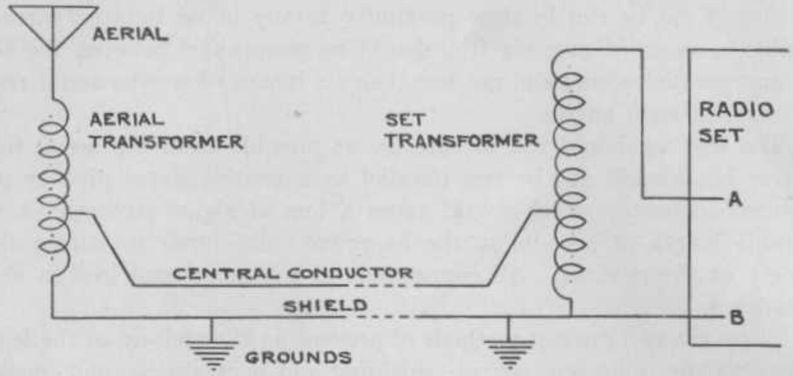

Figure No. 13.—Radio Transmission Line with Shielded Lead-in and Transformers.

(ii) *Shielded Lead-in.*—The radio transmission line may consist of two conductors within a grounded shield or may consist of a single conductor while the grounded shield provides the return path for the radio transmission line. The shield may be directly grounded, or connected through a small choke coil to ground. This choke coil is sometimes mounted in the set transformer case.

(iii) *Set Transformer* (Optional).—The radio transmission system may be connected directly to the aerial and ground terminals of the receiver when a set transformer is not required. It is usually found, however, that an increase in signal voltage at the set may be obtained by placing a transformer between the transmission line and the radio receiver. This transformer is so designed that the impedance of its primary is matched to that of the transmission line and the impedance of its secondary matched to the input impedance of the radio set from aerial to ground terminal.

These radio transmission lines prevent pick-up of inductive interference from the field between the antenna and receiver and also provide a considerable increase in signal voltage at the set by reducing the lead-in losses to a minimum.

(3) Neutralized Lead-in

Another method of preventing pick-up of the lead-in from influencing the radio receiver consists of a two-conductor transmission line with balancing transformers, somewhat similar to the system used for the probe—shown in Figure 10. These transformers are so designed that the lead-in pick-up is neutralized or cancelled and has no effect at the aerial terminal of the receiver. The neutralized system consists of

(*a*) An aerial transformer,
(*b*) A transmission line, and
(*c*) A set transformer.

(*a*) *Aerial Transformer.*—The aerial transformer consists of a primary connected from aerial to the metal supporting bracket, and a secondary connected to the transmission line. The bracket is designed to be clamped to an iron pipe mast, which may be grounded for lightning protection. This transformer requires to be very accurately made in order that the electrostatic coupling between primary and secondary shall be minimum and shall be equally balanced between the two terminals of the secondary. The primary and secondary must be closely coupled inductively.

(*b*) *Lead-in.*—The lead-in consists simply of a twisted pair of rubber insulated, weatherproofed, copper wires, and may be several hundred feet long.

(*c*) *Set Transformer.*—The set transformer is electrically similar to the aerial transformer, its primary being connected to the transmission line and its secondary from the ground terminal to the aerial terminal of the receiver. The ground terminal of the receiver may or may not be connected to ground, as found best by experiment.

Use of Radio Transmission Systems

It must be borne in mind that none of these systems eliminate the noise picked up at the aerial but simply transmit both signal and interference from the aerial to the receiver.

The inductance of the coils of these transformers for both the shielded and neutralized systems may vary considerably. The secondary of the set transformer should, however, be matched to the input of the radio receiver, For receivers having high impedance input the ratio of the set transformer is usually between the limits of 3:1 or 8:1, the greater number of turns being in the secondary for connection to the receiver. The ratio of the aerial transformers is usually somewhat similar, the greater number of turns being in the aerial circuit. The coils of the two transformers connected to the transmission line should be somewhat similar. Some transformers have about 100 turns of 1 inch diameter in the aerial circuit and about 25 turns in the transmission line circuit.

Advantages and Limitations of Improved Aerial System

Although an improved aerial system increases the ratio of signal to noise to such an extent that satisfactory reception can be obtained under normal conditions, there may be periods of poor reception or fading when the field strength of a distant broadcast station may not be sufficient to overcome the background noise.

On the other hand a poor aerial system may provide satisfactory reception at times when the field strength of the received signal is sufficiently great to overcome the local noise level.

COMPARISON OF AERIALS

As the signal strength of night reception varies greatly, and daylight reception is nearly constant, it is more satisfactory to compare aerial systems by listening to broadcast during daylight. A slight difference in aerial systems can best be detected by listening to stations which are just audible above the noise level in daytime.

Grounds

Radio grounds are important for three considerations, i.e.,

(1) Lightning protection,
(2) Reception of Signals, and
(3) The Reduction of Interference.

(1) LIGHTNING PROTECTION

The antenna system should be connected through an approved lightning arrester to a water pipe or driven ground outside the building.

(2) RECEPTION OF SIGNALS and

(3) REDUCTION OF INTERFERENCE

A direct connection from the ground terminal of the receiver to a water pipe or driven ground will usually improve reception. In exceptional cases reception conditions may be improved by omitting this ground or by using a counterpoise consisting of an insulated wire five to fifty feet in length.

All ground connections should be made mechanically secure and electrically perfect. Soldered connections or ground clamps are recommended. Many cases of noise are traceable to loose or corroded ground connections. Ground wires should be as short as possible and not run parallel to nearby house lighting wires. Grounds to water pipes should, preferably, be made near the water service entrance. Where there is a water meter the ground wire should be connected to the pipe on the service side of the meter to avoid the possibility of high electrical resistance.

NOTE.—The following is an extract from Canadian Electrical Code, Part I, Rule 3701 (m)—"Ground Connections shall not be made to Gas Pipes."

SURGE TRAPS

Condensers—Correct Capacity with Regard to Length of Leads

Condensers used for the supression of inductive interference should be selected and installed so as to form a low impedance by-pass for the components of the interfering surge, which lie within the frequency range it is desired to clear of interference.

The impedance of the condenser with leads depends on the total capacity, inductance and resistance of the condenser circuit and the radio frequency under consideration.

The impedance of the condenser circuit may be represented by the equation

$$Z = R + j\left(\omega L - \frac{1}{\omega C}\right)$$

or, in other terms,—

$$Z = \sqrt{R^2 + X^2} \text{ where } X = \left((2\pi fL - \frac{1}{2\pi fC}\right),$$

where Z equals impedance in ohms, R equals resistance in ohms, L equals inductance in henries, C equals capacity in farads, and ω equals 2πf; f equals frequency in cycles per second.

The resistance of this circuit is so small that it may be neglected. The resistance of eight inches of No. 14 B. & S. gauge copper wire at 1000 kc. is 0·011 ohms while the inductance is 0·21 micro-henries, so that at the frequency of 1000 kc. the reactance is 120 times the resistance.

$$\text{Reactance} = 2\pi fL = 2 \times \frac{22}{7} \times 10^6 \times \frac{.21}{10^6} = 1.32 \text{ ohms.}$$

INDUCTANCE

The inductance of commercial condensers of less than 1 mf. capacity varies considerably and some manufacturers advertise that their condensers are especially constructed to be practically non-inductive. The inductance of most condensers, particularly those less than ½ mf. capacity, is usually low compared with the inductance of a few inches of lead. The inductance of the leads has a very important bearing on the efficiency of the condenser surge trap and a few inches of extra leads may make all the difference between the condenser satisfactorily suppressing the interference and being practically useless. In no case should the condenser leads be more than twelve inches in length.

CAPACITY

The correct capacity to select for the suppression of interference in any given case depends largely on the minimum length of lead necessary for the installation. It is seen from the equation that, in order that the impedance may be minimum, $\omega L - \frac{1}{\omega C}$ should be as near zero as possible. It is not possible in the field to make accurate measurements but the following information will be of value. The condenser and leads should be selected to have a minimum impedance about the middle of the band desired, for instance about 1000 kc. for broadcast reception. There is seldom any advantage in using a single condenser of more than 1 mf. capacity even with practically no leads. If leads totalling 3 inches in length are required, ½ mf. condensers are usually best; with 5 inches of lead, ¼ mf.; with 10 inches of lead, 1/10 mf.

Where it is possible to instal condensers with short leads a larger condenser with the correct length of short leads will form a by-pass of lower impedance and, therefore, prove a more efficient surge trap than a small condenser with long leads. If, however, it is impossible to connect the condensers without using long leads it is found that the smaller capacity with its correct length of leads is better than using the large condenser in this case.

Where it is not practical to instal the larger condenser with appropriate short leads, and it is found that a 1/10 mf. condenser with the 10-inch leads will not suppress the interference sufficiently, several of these 1/10 mf. condensers may be used in parallel, each with its own separate leads. This latter arrangement has proved very satisfactory in suppressing interference from electric railway generators when none of the other methods tried gave satisfactory results.

PUBLIC UTILITIES LINES AND APPARATUS

Investigation of Interference

A complete investigation of interference from high tension lines affecting broadcast listeners' reception should include a detailed investigation of

(1) Radio receiving installation;
(2) Intermediate circuits which may conduct the interfering surges from the power line on which they originate;
(3) The power line;
(4) The actual source.

(1) Radio Receiving Installation

The radio receiving installation should be inspected and any excessive coupling between the radio installation and the house lighting, communication, or other circuits, should first be eliminated.

Consideration should be given to the installation of an aerial system with no pick-up except from the antenna proper.

(2) Intermediate Circuit

If interference is brought to the radio installation by the medium of an intermediate circuit, such as telegraph, telephone, street lighting or distribution wiring, an investigation of such circuits may conveniently be carried out by using the absolute direction finder and probe antenna. Such investigations are illustrated by the following three examples:—

Distribution Lines conduct Interference originating on High Tension Lines.—Interference of a type similar to that produced by high tension lines was affecting reception remote from any such line. Investigation was

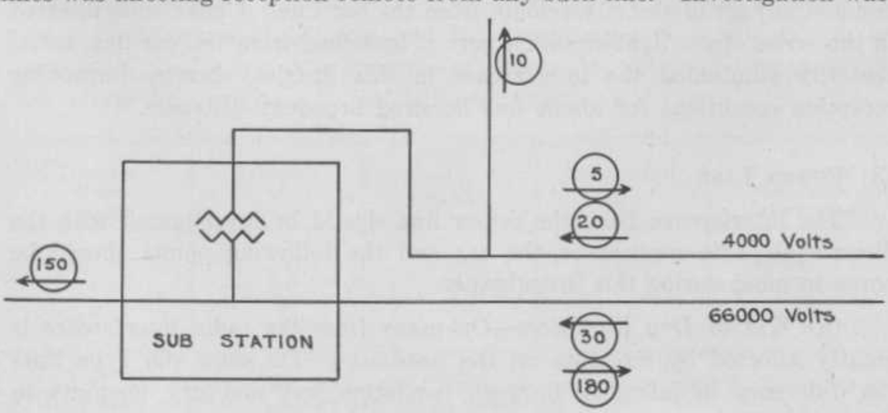

Figure No. 14.—Diagram Showing Direction of Interfering Surges on Distribution Lines.

conducted, using an automobile equipped with an "absolute direction" or "sense" finder, and comparative measurements were taken under the various branches of the distribution circuit, and under the high tension power line in the vicinity of the sub-station. The intensity of the interference travelling in each direction on the various branches of the distribution circuits and power line was measured and the results are indicated in Figure 14. These tests showed that the pick-up of high tension interference by the distribution system occurred principally where the two lines ran parallel in close proximity, rather than at the substation.

The arrows represent the direction of the surge as indicated by the "sense finder," while the figures within the circles represent intensity of interference in arbitrary units. Measurements were made with interference car directly under the lines.

Interference carried by Telephone Circuit.—Severe interference from cotton mill equipment was seriously affecting radio reception for most of the broadcast listeners in the town in which the mill was located. The plant was supplied by feeders from the local distribution system, through a transformer structure on the mill property, and, as no interference was noted on these distribution feeders, it was apparent that any surges carried by the mill secondary circuits were by-passed to ground at the transformer structure. The telephone lines to the mill 'phone were found to be conducting the interfering surges to all the telephone circuits in the town.

By inserting small choke coils of 350 turns in each of the two telephone lines where they entered the mill property, the interfering surges were prevented from reaching outside circuits and radio reception was cleared for the broadcast listeners.

Interference carried by Street Light Circuit.—Street car interference was found to be conducted on a single series street light circuit into a residential part of the city remote from the car line. Choke coils inserted in the series street light circuit, where it branched from the car line, satisfactorily eliminated the interference in this district, thereby improving reception conditions for about five hundred broadcast listeners.

(3) Power Line

The interference from the power line should be investigated with the directional radio receiver in the car and the following points should be borne in mind during this investigation.

(*a*) *Wet or Dry Insulators*—On many lines the radio interference is greatly affected by moisture on the insulators. On some pin type lines the difference in intensity between insulators wet and dry amounts to more than 20 to 1, measured in volts output of the receiver.

(*b*) *Wet and Dry Poles.*—Dry wood poles and cross arms provide insulation in series with the porcelain insulator and, thus, reduce the potential across the insulator. When the pole and cross arm become wet and conducting, full line voltage is impressed across the insulator.

(*c*) *Coupling from High Tension Line to Radio Receivers.*—The height from the line and horizontal distance from line to receiver affect the interference pick-up. Any conductors, such as telephone or distribution wires, between the high tension line and the receiver, may affect this coupling. Pot heads (connecting open wiring to cable), branch lines, ground wires, and even transpositions may cause variations in the radiation of interference. It has been observed that when the loop of the radio receiver is placed below a high tension line within a closed circuit, consisting of two nearby ground wires connected to a sky-line or ground conductor, the pick-up of the radio receiver was very much greater than when the loop of the receiver paralleled the line remote from such ground wires. On this account measurements of high tension interference should be taken, using an antenna rather than a loop, and selecting a location immediately under the line where it is about 25 or 30 feet high and as free as possible from other conductors.

(*d*) *Concentrated or Distributed Interference.*—In the past it has been difficult to differentiate between interference originating at an individual source and an accumulation of interference from lesser sources uniformly distributed along the power line. The fact that interference originating at one source may be conducted along some power lines for a distance of 10 or 15 miles and radiate through this entire length of line added to the difficulty. With the new sense finding radio receiver, however, it is possible to obtain the sense or absolute direction from which interference reaches the receiver, and, thereby, distinguish between the normal interference of the line and that originating at a sub-station, or some fault on the line. An example of the results obtained from a 33,000 volt power line is given in the following table:—

Distance from sub-stn.	Intensity of Intf.[1]	Sense Ratio[2]	Normal Intf. of Line	Intensity of sub-station Interference
100 yds.	150	10:1	15	150
4 mi.	100	8:1	12	100
6 mi.	50	5:1	10	50
12 mi.	10	1:1	10	nil.

[1] Arbitrary units derived from output voltmeter readings on radio receiver in automobile placed in definite location relative to power line.

[2] Relative intensity of the surge coming from the substation and that coming from the opposite direction.

Previous to these tests with the sense finding receiver the intense interference had been noted at considerable distances from the sub-station and it was supposed that the interference originated principally from the line insulators. These tests, however, proved that the greatest part of the interference originated in the sub-station. Further investigation proved that a great deal of the sub-station interference resulted from electrostatic discharge from lines to interior surface of entrance bushings.

(4) Actual Source

The investigator makes use of special radio equipment, to determine the actual source of interference or the approximate location of same. If this cannot be determined with the facilities available, the co-operation of the officials of the utilities concerned is obtained in switching or other tests necessary.

The Absolute Direction Finding Equipment in the car will indicate the direction along the lines that the interfering surge is travelling and, in this way, the interference can be traced to a source at a sub-station, transformer structure, or individual pole or tower.

The Potential Probe Antenna will indicate the conductor on which the interfering surge is greatest.

The Radio Frequency Current Probe, which consists of a pick-up coil connected to the radio receiver by a neutralized r.f. transmission line, will indicate the circuit, such as ground wires from lightning arresters, transformers, switches, etc., carrying radio frequency current.

The Portable Radio Receiver is used for investigation work in locations in which the interference car cannot be operated. A portable receiver designed especially for interference investigation is now manufactured in Canada. The receiver, which is self-contained, includes loop, batteries and 'phones, has outside dimensions of 14¾ inches by 11¼ inches by 5¾ inches and weighs 20 pounds.

Treatment of Insulators

Considerable progress has recently been made in the development of practical methods of eliminating electrostatic discharge from conductors to bushings or pin type insulators.

The manner in which this electrostatic discharge produces radio interference is fully described in Bulletin No. 2, pages 90 to 93.

The two principal methods of eliminating this type of interference are referred to under paragraph headed "Bushings," page 94, and include

(*a*) filling air space with insulating material, and

(*b*) painting with conducting paint.

Filling Air Space with Insulating Material

Asphalt emulsion has been found to be a suitable material for this purpose as it can be readily applied to the top of pin type insulators or may be used for filling in tubular entrance bushings. It is most important that this material be applied in such a way as to displace all the air in close proximity to the conductor. Any void which may be left in the electrostatic field surrounding the conductor may cause discharges resulting in more intense interference than that produced by an untreated insulator or bushing. When this compound is applied to pin type insulators the tie-wire should be removed, the compound applied to the line and tie-wire grooves of the insulator and the tie-wire then replaced before the compound hardens.

The insulating compound for this purpose must remain reasonably plastic under all weather conditions. If the compound is stressed beyond its elastic limit so as to crack, voids are introduced across which electrostatic discharge will occur and probably cause more interference than before the insulator was treated. This method of treating insulators is, therefore, not suitable in locations where the swing or vibration of the line will cause a movement of the conductor relative to the insulator greater than that which the elasticity of the material will allow for without cracking.

Conduction Paint

Conduction paint, which is now marketed in Canada, may be used on insulators and bushings to short-circuit air spaces within the electrostatic field of the conductor. Such paint should have the following properties:—

(1) The paint must adhere closely to the porcelain. Air spaces between the paint and the insulator would cause voids where electrostatic discharge would occur and considerably increase the intensity of the radio interference.

(2) The paint must be reasonably elastic to withstand the vibration of the line. The conductivity of the paint should remain constant and no spots or "islands" should occur whereby sections become separated from the rest of the material. Electrostatic discharges may occur across any discontinuities in the paint.

When treating a pin type insulator with conduction paint the insulator should, first, be removed from the line and thoroughly cleaned, so that the paint will adhere to the porcelain. The pin hole should then be painted and the insulator replaced on the pin before the paint sets. The next step is to paint the top of the insulator and tie-wire groove, extending the paint one inch beyond the groove on the surface of the insulator. The line should be tied before the paint sets, and the tie-wires and section of the line near the insulator given a coat of conduction paint. Any paint, found to have dripped on sections of the insulator not requiring treatment, should be carefully removed.

It is essential that this conduction paint be correctly applied and it is, therefore, necessary to interest the workman in every detail, as any carelessness in the application of the paint may tend to increase rather than decrease the interference in question. It is reported that conduction paint on insulators, which were treated three years ago, has satisfactorily withstood weather conditions and shows no sign of deterioration.

A system using conduction paint appears to have an advantage over a system using insulating compound if the conductor is liable to movement relative to the insulator beyond the elastic limit of the material. Such a movement will produce voids between the conductor and the insulator and cause severe interference when insulating compound is used, while such voids on insulators treated with conduction paint will not necessarily cause interference provided that they are short-circuited by the paint.

Electric Railway Systems

Progress has been made in the study of interference from electric railway systems and reception conditions have been decidedly improved in a number of cities where suppressive means have been applied.

No general method has been found applicable to different systems, even though equipment may be similar.

In order to simplify the investigation of interference from such systems, it is advisable to deal separately with each individual type of interference. Thus, as a general rule, air compressor motors on all rolling stock are first checked and the interference from same eliminated. The car buzzers and door signal systems are then dealt with. Interference from traction motors and other sources can then be more readily recognized and investigated.

While all these sources cause severe interference, the elimination of any individual type may not produce noticeable improvement in broadcast reception conditions generally, until all are dealt with.

It has been found that a material reduction in the interference caused by the operation of electric cars can be obtained by rearranging the wiring of the car equipment; this applies particularly to the air-compressor motor, traction motors and car signal systems.

Compressor Motors.

On many systems, compressor motors have been found to cause the most severe interference, and fortunately this source of interference may be very simply eliminated by reversing the leads and grounding the negative brush to the frame of the compressor with a short lead. Figure No. 15 indicates three alternative wiring arrangements frequently used on compressor motors:—

Figure (*a*) shows the field coils on the positive side of the armature and the negative brush of the armature grounded to the frame with only a few inches of lead. Compressor motors connected this way cause no appreciable radio interference.

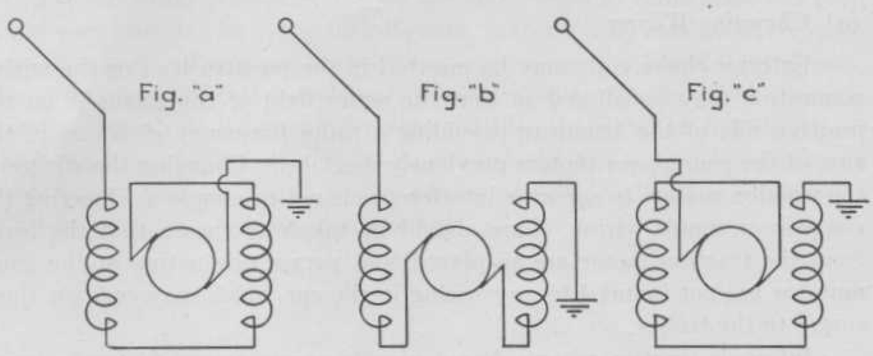

Figure No. 15.—Alternative Wiring Arrangements of Compressor Motors.

Figure (*b*) shows one section of the field coils on each side of the armature. This method of connection causes more or less interference according to the arrangement of the leads with respect to the other car wiring. Frequently, very little interference is caused when the negative lead to the compressor is directly grounded to the frame with only a few inches of lead.

Figure (*c*) shows the armature on the positive side of the field coils. This arrangement causes the greatest amount of interference.

A radio investigator working on a large system was able to determine from the intensity of the interference from a great number of cars, which of these three arrangements was used in connecting the compressor motors of the individual cars.

On a number of systems in Canada all the compressor motors have been connected according to Figure 15 (*a*), thereby considerably reducing the radio interference. On systems where the general noise level is not intense broadcast listeners appreciate this change. On other systems, however, although the radio investigator records a considerable reduction, the remaining interference is such that the broadcast listeners do not benefit materially until further action is taken in connection with the remaining sources.

TRACTION MOTORS

Radio interference from traction motors varies considerably both with the type of motors used and with the wiring arrangements.

Two methods of suppressing the interference from traction motors can be employed;

(*a*) changing the wiring, and
(*b*) the installation of condensers.

(*a*) *Changing Wiring*

Exterior choke coils may be inserted in the positive lead or the wiring connection may be altered so that the series field of the motor is on the positive side of the armature providing a radio frequency choke as in the case of the compressor motors previously described. Changing the wiring to the traction motors to suppress interference is not as simple as changing the compressor motor wiring. Care should be taken to ensure that the leads from the traction motor are so placed that surges originating at the commutator are not induced to any wiring in the car which may conduct these surges to the trolley.

Interpole traction motors do not usually cause appreciable radio interference. This is partly due to improved commutation and partly due to the interpole winding acting as a radio frequency choke.

(*b*) *Condensers*

Condensers having an extremely low inductance are necessary and require to be installed with the correct length of lead so as to form a by-pass to components of the interfering surge within the broadcast band. The reason condensers across the brushes have frequently failed to suppress interference is on account of the condenser circuit not being sufficiently low in impedance at broadcast frequencies. The capacity and inductance of the condenser circuit should be such as to provide a by-pass of extremely low impedance. The inductance of the leads of the condenser, although extremely small from the point of view of an electrician who is accustomed to dealing with power circuits, plays a very important part when connected in series with a condenser used to carry radio frequency currents of the order of 1,000 kilocycles. The length of lead of the condenser depends on the capacity and internal inductance of the condenser. Usually a "non-inductive" condenser of 0·1 mf. capacity connected to leads 10 inches long will have its lowest impedance at about the middle of the broadcast band and will be sufficiently broad in tuning to reasonably cover the band.

The most satisfactory method is the use of condensers having one side directly grounded to the case and the case either bolted or spot welded to the frame of the motor. The other side of the condenser should be connected to the brush by means of No. 18 wire insulated to withstand high voltage. No fuse is necessary as the small wire of the lead will give sufficient protection. Condensers are required from each brush of each motor to the frame. The negative brush requires a condenser because the impedance of the few feet of power conductor from the negative brush to the frame would be sufficient, at a frequency of 1,000 kilocycles, to allow considerable surge voltage to be built up at this point.

The reduction of interference by the application of condensers has been found very effective on many installations, both by tests conducted by radio inspectors and by the improved reception experienced by broadcast listeners. The effectiveness of these condensers is illustrated by the fact that on many occasions broadcast listeners have reported the number of an individual car which was interfering with their reception, and the power company, on inspection of this car, found that a condenser installed for the suppression of interference had become disconnected.