Proceedings

of the

Radio Club of America

Incorporated

June - 1929

Volume 6, No. 6

RADIO CLUB OF AMERICA, Inc.
55 West 42nd Street :: New York City

The Radio Club of America, Inc.

55 West 42nd Street :: New York City

TELEPHONE — LONGACRE 8579

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PROCEEDINGS
of the
RADIO CLUB OF AMERICA

VOL. 6 | JUNE, 1929 | NO. 6

SERVICING RADIO RECEIVERS

By JULIUS C. ACEVES

Amy, Aceves & King, Inc.

Delivere Before the Club, March 13, 1928

THE various tasks involved in servicing sets may fall under the headings of installation, maintenance, and repair of radio sets. Frequently simple inspection is sufficient to locate the troubles which in many cases, originate from misuse of the set for lack of ability to operate it—in fact, for lack of ordinary common sense.

Leaving aside the installation of sets, which is not the main purpose of this paper, let us examine the problems that the service man may be confronted with, and then suggest some general methods that will guide him to the solution in the majority of the cases. Then we will exemplify some special treatments in exceptional and involved cases.

A radio set comprises:

I. Several sources of electrical energy.
II. An r.f. amplifying system.
III. One or more frequency converters.
IV. An a.f. amplifying system.
V. An electrically-operated sound reproducer.

I. The sources of electrical energy are:

1. From the radio waves collected by an antenna or loop.
2. From the A, B, and C voltages furnished by batteries or house current tap.

The troubles from the first source may be ascribed to—

(a) Insufficient aerial, and
(b) Defective aerial and ground system.

Under (a) there may be—open or short circuits, and loose connections in the pick-up system. Continuity test will reveal the defects under heading (b). However, for the present, no remedies will be suggested until we list the most common troubles.

2. The sources of power for the operation of the tubes are manifold, and the troubles may come from—

(a) Insufficient voltages (b) Excessive voltages (c) From the presence of other than continuous currents in the supply leads.

These currents are in most cases harmonics of the frequency of the power supply line; at times the fundamental may be present, and in no few instances, currents originating from other electrical devices connected to the same lines. Of the latter, the transients are the most objectionable and difficult to eliminate, especially in sets for d.c. These interferences may come, nay, they actually come at all times via the radio pick-up system, particularly by antennae that happen to run near radiating electrical apparatus such as sparking motors, X-ray machines and high tension sparking devices for ignition capable of producing shock exitation. In this case there is little hope for remedy as the interfering E.M.F's contain practically a continuous spectrum of frequencies, consequently including the signal frequency.

II. In the r.f. system, as in the rest of the vacuum tube networks in the radio set, troubles may be due to—

1. Poor amplification. 2. Poor tuning.

In the former case, most troubles come from (a) defective or worn out tubes, (b) by their operation at improper A, B, or C potentials. However, the r.f. system has troubles of its own, mostly due to (c) regeneration and oscillation, and (d) excessively sharp or broad tuning, or no tuning at all. The super-heterodynes involve more considerations than we can discuss at length now.

III. The frequency converters have for their function to re-create either directly or by means of an auxiliary r.f. system, the original modulating wave at the broadcast station. They are called detectors and in most instances tubes with or without a condenser-and-leak accomplish the desired result. In the superhets, there is a conversion of frequency at the first detector, which does not re-create at once the modulating wave, and here the troubles multiply themselves "ad infinitum" in home-made sets, as well as in some commercial sets involving harmonic oscillations and detection in the same tube. The chief difficulties experienced in these frequency transformations are originated by the presence of harmonics in the local oscillator, giving rise to a multitude of radio frequency currents interfering with each other and thereby distorting the signal very badly. In some of the latest models of high-gain r.f. sets, the detection where the modulating frequency is re-created (second detector in superhets) the tendency is tó eliminate the condenser and leak and use the curvature of the plate current characteristic. This system will reduce the detector troubles to a minimum. In the detector that brings back the original modulating wave, the troubles may come from—

1. Operation of tube at improper voltages.
2. Open, short circuited, or defective condenser-and-leak.

IV. The a.f. system is responsible for most, but not all, the troubles from distortion in a radio set. It rarely fails to work entirely, and when it does it is due as a rule to defective tubes or to lack of proper A, B, or C voltages. Open and short circuits in this system usually weaken the signal to almost inaudible strength, but poor tone quality may come as a result of several factors, of which the most common and important are:

1. Bad tubes.
2. Poor transformers.
3. Bad plate resistors and leaks.
4. Short-circuited turns in the transformers.
5. Saturation of iron cores.
6. Coupling between stages, particularly between power stage and detector grid or plate returns.
7. Impedances not properly matched in the system.
8. Power stage of insufficient undistorted power capacity of the volume of sound required.
9. Periodic fluctuations in the B and C voltages commonly known as "motor boating."
10. Loose connections.

THE COMMON TROUBLES

OF ALL these items, Nos. 1, 7, and 8 are the most common in the modern radio receiver, because all the latest sets have been designed with high-grade transformers where care has been taken to match the impedances of the tubes to the transformer windings, and the cores are so designed that when the tubes have the proper C voltage the steady component of the plate current will not saturate the iron cores. As to resistance-coupled sets, there are so few in existence that little trouble is to be expected from items 3 and 4; however, the greatest malady of such sets is caused by periodic fluctuations of "B" voltage which produces a sound in the loud speaker similar to the chug-chug of a motor boat engine, and hence the popular term attached to this sort of trouble. It comes from the operation of resistance-coupled sets from filters that are not suitably designed for them, and the action is so well-known that it will not be discussed at length. Battery operated sets rarely, if ever, "motor boat." The most effective remedy is effected by the use of smaller coupling condensers or smaller grid leaks, or both. If a high capacity condenser is available, it usually stops motor boating when connected across the "B" voltage supply leads.

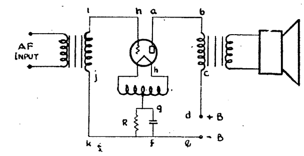


Fig. 2

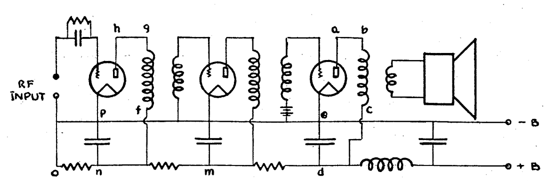


Fig. 1

The coupling between the stages is a fault found even in well-known standard sets in the market where reduction of number of parts and lower first costs have driven the designer to the minimum of parts. Usually, the coupling takes place between the power stage and the detector circuit, or at the power stage itself. This subject deserves further elucidation.

Consider the circuit Fig. 1 and follow the path of the variable components of the plate current of the power stage. Starting at the plate *a*, they will go through the windings of the output transformer *b,c* to the terminals of the "B" eliminator at *d* and there it has two parallel paths; one through the condenser *e* to the negative terminal, and one through the resistance or voltage divider *mno*, and it is through this second path that it will reach *n* and some part will go through the resistance to *o* and some through *g* and *h*. The potential drop across the filter condenser *n p* will be applied across the primary of the first audio transformer through the plate circuit of the detector tube and current will flow through *n f g h p*, generating thereby a voltage across the secondary, which will combine with the voltage due to the signal coming from the detector in such phase relationship as will be determined by the frequency and the constants of all the apparatus in the network. The two E.M.F.'s will react upon each other so as to have different effects at various frequencies and hence the distortion. Usually at high frequencies the condensers have such low reactance that the effect is negligible, but at 50 cycles this may not be so in some sets with the usual result that the bass notes are considerably reduced in volume. Then consider what happens in the power stage itself when operated by alternating current, and improperly designed circuit. In Fig. 2, if we follow the path of the variable component of the plate current, it will be clearly seen that it is path *a b c d e f g h*, and a common portion with the path of the grid circuit *g h i j k f g*, and, if the condenser *f g* has an appreciable reactance, there will be a drop across the resistance *r*, which will introduce an E.M.F. in opposition to the secondary voltage of the input transformer in the grid circuit, causing a reduction in the lower frequencies for which the reactance of the condenser is not negligible.

V. The sound reproducer is the least developed of all the instruments that enter in the construction of the radio receiver. It has advanced by leaps and bounds in the last year or two, but nevertheless it is not perfect yet. It is safe to say that most of the acoustic monstrosities that we hear come from poor speakers. If I were given the choice between a poor set with a good speaker, and a good set with a poor speaker, I would take the latter. The speaker itself may not be blamed at times, nor the set alone, but the use of a speaker with a set for which it is not matched. The main sources of troubles with speakers are: 1, Lack of adjustment of air gap. 2. Direct current through the coils exceeding safe value. 3. Open or short circuits in the windings or leads. 4. Cones or armatures not centered properly. 5. Poor location giving rise to resonance at certain frequencies. 6. Loose parts that can emit most annoying rattles. Under heading 5 comes the acoustic-electric regeneration that takes place by the mechanical vibrations of the tube elements produced by the air vibrations from the loud speaker acting upon the tubes, particularly upon the detector.

DISCOVERING THE FAULTS

Part II. Having listed the most common difficulties experienced in connection with the whole receiving plant, let us now suggest methods to discover the faults without wasting unnecessary time. For the purpose of refreshing our recollections, we give in tabular form a list of the troubles and their sources, so that by inspection of the table the remedies will become obvious in many cases.

It will be apparent that bad tubes may be blamed for trouble in almost every department of the radio set. In practice, bad tubes are responsible for more than fifty per cent. of the failures of sets, and should be investigated first, starting from the detector toward the power stage, and then going to the r.f. system. To this end, give a gentle tap to the detector, and if the speaker emits a sound like a chime it is perfect. If it does not, tap a little harder the first audio stage tube, and if there is no sound, although all the filaments are lit, a more thorough investigation must be followed.

It will be noted that a source of much trouble, and one that appears in almost every item in the list, is the

General Troubles

I. In the sources of energy—		
1. Pick-Up System.	(a) Insufficient Input to set.	—(a) Aerial too short. —(b) Aerial shielded. —(c) Loop in wrong direction. —(d) Set in bad location.
	(b) Opens and shorts.	
	(c) Loose connections.	
2. A, B, and C Source	(a) Insufficient Voltage	(a) Bad tubes. (b) Opens and shorts.
	(b) Excessive Voltages	(a) Poor design. (b) Wrong connections. (c) Opens and shorts.
	(c) Extraneous currents.	(a) A.C. hum due to defective filtering. (b) A.C. By induction or conduction or capacitance. (c) Transients.
II. In the R. F. System—		
1. Poor amplification.	(a) Bad tubes.	
	(b) Improper Voltages	(a) Opens and shorts.
2. Poor tuning.	(a) Broad	(a) Condensers not tuning all alike at all frequencies. (b) Opens or shorts. (c) Too long an aerial.
	(b) Sharp	(a) Regeneration due to defective design or operation or use of wrong tubes. (b) Neutralization incomplete. (c) Excessive B voltage.
III. In the Detector —		
1. Single Detection.	(a) Lack of sensitivity	(a) Improper voltages. (b) Open or short circuits. (c) Low resistance leak. (d) Short circuited grid condenser.
	(b) Distortion.	(a) Improper voltages. (b) Open leak. (c) Improper capacity of condenser. (d) Open circuits.
2. Double Detection.	(a) and (b) same as above.	
	(c) Harmonics from the oscillator.	
	(d) Unsteady oscillator frequency.	(a) Poor design. (b) Excessive feed back.
IV. In the A.F. System—		
1. Feeble or no response.	(a) Bad tubes. (b) Opens and shorts. (c) Wrong connections.	
2. Distorted output.	(a) Poor design.	(a) Poor transformers. (b) Saturated cores. (c) Regeneration, positive and negative. (d) Power stage of insufficient output wattage.
	(b) Poor construction, assembly or operation.	(a) Coupling through eliminator. (b) Impedances not properly matched. (c) Motor boating
V. In the Loud Speaker.—		
1. Feeble or no response.	(a) Opens and shorts.	(a) In the leads. (b) In the "motor." (c) In the power supply in dynamics.
	(b) Poor adjustments.	(a) In the air gap. (b) In the diaphragm or cone.
2. Distorted reproduction.	(a) Same as above.	
	(b) Impedances not matched.	
	(c) D.C. through "motor."	(a) Shorted coupling (b) Absence of coupling circuit to power tube.
	(d) Loose parts.	(a) Loose Wiring. (b) Sympathetic vibrations on surrounding objects.
	(e) Insufficient air column.	(a) Short horn. (b) Short baffle board.
	(f) Regeneration	(a) Acoustic resonance. (b) Electric feedback. (c) Acoustic-electric back-coupling to tubes in set.

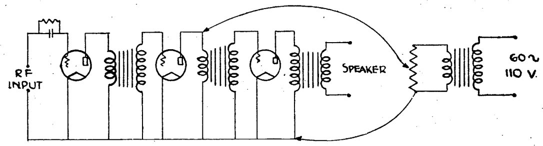


Fig. 3

presence of open and short circuits. The general remedy is a systematic continuity test. In any of the well-known radio sets, the manufacturer gives the proper procedure for carrying out such tests, and it is not our aim to repeat what is usually said there, but to point out how the continuity tests may be made rapidly and without having to dismantle the set, if possible. Let it be pointed out again that we are now concerned with the most common faults, which ought to be easy to trace, but that by lack of method may take much time to the average trouble hunter. The difficult cases will be illustrated later. I say illustrated, because they cannot be enumerated, and the ingenuity and initiative of the operator, coupled with a long experience, is the only means of solving the problem.

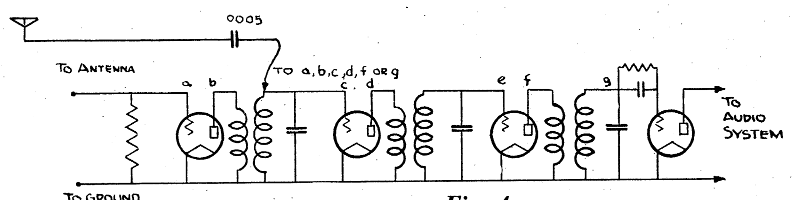


Fig. 4

USE OF VOLTMETER

THE greatest friend of the repair or service man is the high resistance voltmeter. This valuable instrument, with a dry cell, can trace a good percentage of the open and short circuits.

Let us illustrate the procedure in a concrete case. Take a radio set that refuses to speak at all. It does not even emit a murmur in the speaker. All the tubes light to approximately the proper brilliancy. Connect the negative terminal of the voltmeter to the "A" supply leads or to the frame or chassis and with the free end "positive" touch the plates of all the tubes, starting from the power stage. Improper "B" voltages will at once be discovered wherever they occur.. Then, with the positive terminal to the B, touch all the ends of grid circuit terminals.

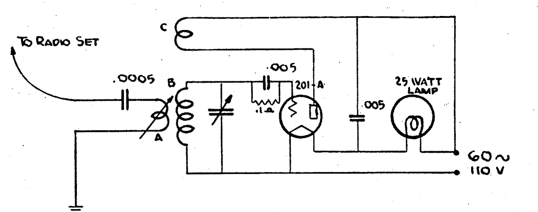
Again, let us now suppose that there is "B" voltage at all the plates, but the power tube gets unusually hot. Measure the "C" voltages, and that will tell the story. Now let us suppose that having found that, all the tubes, at least all those in the audio system have the right voltages applied to their respective elements, but yet the speaker is "dead." Disconnect the speaker and see if there is an open in the leads by inserting the voltmeter in series with the speaker and connecting both of them across the B voltage. If the voltmeter shows a continuous circuit, the loud speaker may be prevented from speaking by mechanical derangement, or by an open circuit in the secondary of the transformer that steps down the voltage from the power tube plate circuit to the moving coil attached to the cone. A simple inspection may tell which is the case, and if the cone is quite loose to move in and out, then connect the voltmeter to a source of potential and test the secondary circuit for continuity.

Often it is very useful to determine rapidly the d.c. resistance of some component part or circuit of a radio set. The voltmeter comes here very handy. With a $4\frac{1}{2}$-volt "C" battery and a Weston 8-volt scale (1000 ohms per volt) voltmeter which is very much in use for radio service, the resistance may be found by the equation: (by ohm's law)

$$R = \left(\frac{4.5}{e} - 1\right) \times 8000$$

Higher resistances, such as leaks, may be measured by using the 200-volt scale and a 45-volt battery; then,

$$R = \left(\frac{4.5}{e} - 1\right) \times .2 \text{ (in megohms)}$$



A=Rotor winding, B=Grid winding, C=Plate winding of ordinary 3 circuit tuner

Fig. 5

There are in the market combinations of meters and dry cells with the scale calibrated directly in ohms and

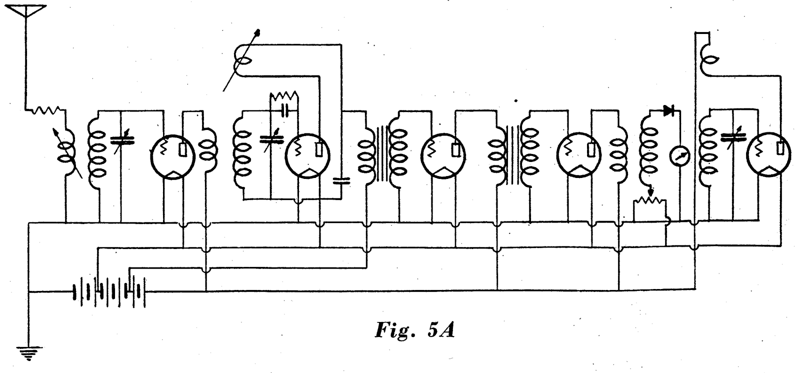


Fig. 5A

it is advisable to have one of those instruments or ohmmeters at hand in the laboratory. If there is no voltmeter available, the headphones or even the loud speaker may be used in great many instances for continuity tests. There are also devices containing a plug that, inserted in place of the tubes, will permit measurements of A, B, and C voltages, and plate current in any tube socket of a set. The tube that was removed from the set is inserted in an auxiliary socket.

The easiest way to get at the grid and plate connections of the tubes, when the above mentioned apparatus is not at hand, and it is necessary to measure the potentials at the tube elements while the tube is in operation, is to use a piece of insulated wire with a little bend at the extremity where the insulation is removed so that it will get under the tube base and touch the prongs by lifting the tube very little from its socket if it is of the UX type.

There is a second kind of continuity test; not merely of electrical circuits, but a continuity of amplification. It can be easily accomplished in the audio system by means of a little bell-ringing transformer, the primary of which is attached to the a.c. line and one terminal of the secondary to the ground, or filament terminal. Then with the other end attached to a small condenser, say $\frac{1}{10}$ mfd., touch the grid and plate circuits of the various audio stages starting from the plate of the power tubes, grid of the same, plate of the first audio, grid, plate or detector and grid of the same tube. Note the response of the loud speaker to such applications, and from the result it will be easy to locate the trouble in the audio system. A small potentiometer of any value from 15 to 200 ohms, more or less, may be used across the low tension secondary of the bell-ringing transformer to get an approximate idea of the amplification as you pass from one stage to the next or from the plate to the grid of the same tube. Fig. 3 shows the circuit and illustrates the method to be followed. In d.c. districts, the bell-ringing transformer may be replaced by a hummer made of a microphone and a telephone receiver put face to face so that they will produce oscillations. If these instruments are not at hand, the clicks from the loud speaker may give an indication of the performance of the audio system, simply by short circuiting the plates and grids to the filament by a piece of wire.

The continuity of amplification of the radio frequency system may be traced rapidly by the use of a small condenser in series with the antenna and with the other end of the condenser lead, touch the grid and plate circuits of each successive r.f. stage. If the antenna is sufficiently long, some signal should be heard even in the grid of the detector. As soon as the least response is heard, go back with the exploring wire toward the antenna end until the signal is lost. Be sure to retune every time. Fig. 4 illustrates the procedure. In the absence of a long aerial, a buzzer-exited tuned circuit may be used as a source of r.f. However, better still, a tube oscillator with modulations, such as illustrated in Fig. 5, is easy to make and gives quite satisfactory results.

In a similar manner, when a radio set starts "squealing" at r.f. the source of oscillations may be located by short-circuiting the various grids and plates to ground through a by-pass condenser.

USE OF OSCILLATOR

A VERY convenient and useful combination a.f. and modulated r.f. source that may be used to determine approximately the amplification of one or more stages, and operates from 60 cycles, 110 volts, is illustrated in Fig. 5a. The audio frequencies are multiples of 60, by the distorting action of the tube. With the switch S to the left, it furnishes r.f. as in Fig. 5, and to the right the grid is connected to the line through a protective resistance R and the tube acts as an amplifier only during every half cycle, but purity of the tone is not necessary.

The most exasperating conditions in radio servicing are those when the trouble appears and disappears irregularly. At times the set works perfectly and at times it either ceases to work or does so in a distorted manner or with a much reduced intensity.

In cases of insufficient signal, where every test has been applied and all the elements of the set seem to be in good condition, or, when a set is to be installed in a place notorious for poor reception of some particular station, or for all, it is desirable to measure the voltage coming from the aerial by means of a portable receiver. Fig. 6 shows the essential connections of a very simple receiver that has been found extremely useful to measure the voltage distribution of a loaded antenna.

The instrument contains one r.f. stage, detector and two audio stages. In the last stage, a galvanometer with a crystal rectifier gives a deflection which is a function of the signal strength. Two controls, calibrated, in DB permit the adjustment of the amplification so that a given reading in the galvanometer is obtained. The first one is a variable coupling from the aerial to the first r.f. tuner, 600 ohms are added in series so that an attenuation box of conventional design may be used in the calibration. The second control is a tickler coil, and the regeneration although dependent upon the frequency, is easy to determine the number of DB's that a given motion of tickler dial is equivalent in terms of the first control. For stations in the middle of the broadcast band, the regeneration is practically the same.

An auxiliary tube, oscillating at a frequency that will give audible beats with the carrier, will permit test irrespective of the nature of the program broadcast, as the frequency of the beats between the local oscillator and the carrier remains substantially constant, and, therefore, the needle of the galvanometer is not dancing all the time. Care should be exercised not to take readings without carefully retuning for maximum deflection.

The results may be obtained with sufficient accuracy for all practical purposes. The sensitivity of sets can thereby be determined.

A bad connection which makes and breaks is something hard to locate. However, the character of the interruptions may throw some light, sometimes. For instance, if there are changes from soft to loud in the signal strength, but the quality of the reproduction is the same, chances are that the bad contact is in the antenna system or in the radio-frequency amplifier. Some other times, when the signal goes down very much, the breaking may have occurred in any place of the set even in the magnetizing winding of a dynamic speaker. The general procedure should be to start from the loud speaker end toward the antenna. The loud speaker may be tested by applying the "B" voltage to its terminals intermittently and listening for the clicks, which ought to be very loud, and a spark should be plainly visible at the breaking points. Then examine all the "A," "B," and "C" leads, and pull them gently in and out to see if they are not broken and then proceed with the voltmeter while the set is gently jarred in search for loose connections. One of the most common sources of make-and-break troubles is at the condenser-and-leak of the detector. It happened recently that a standard radio set was in operation for over two months giving excellent results, and all of a sudden all kinds of noises developed, such as produced by a stone crusher or a frying pan. Every connection was checked up and all the tubes had the proper voltages and sometimes by wiggling a wire the noise would start ferociously. The wire was traced and nothing could be found the matter with it. Finally the set was opened up and an inspection showed nothing wrong at first. As it was made so that operation either from the radio or from a phonograph was possible, a comparison in the behavior in each case led to locate the trouble in the radio end. The antenna was connected through insulation condenser to the various stages and patiently waiting for the noise to come, and when it appeared of a sudden, it was traced to the detector. There was found a piece of solder between the grid condenser and a small potentiometer across the "A" wires that was causing a change of biasing voltage whenever it touched the wire of the potentiometer and the shell of the grid condenser. Sometimes when the patience of the experimenter is about to be exhausted, a rather drastic remedy may be applied to find a poor connection when other methods lead nowhere. With a large tungsten lamp, or a soldering iron or a toaster or something that will pass a large current from the mains, the search for the poor connection may be undertaken by allowing the current from the electric light supply through the protective device above mentioned in series to pass through the ground or antenna wires and see if a small arc is formed where it breaks. Fig. 6 illustrates the circuit. By using a smaller wattage lamp, it is possible to make continuity tests rapidly and conveniently when the voltmeter is not available. The brightness of the lamp can give a measure of the current and, therefore, the resistance of the circuit may be closely estimated. If some small wire happens to be entangled to the aerial or this touches something else, it is possible to see the spark by night or possibly the point where the wire arced during the application of the line current. In the above manner an intermittent short circuit of one of the aerials at Columbia University was discovered near an insulator that had all the appearances of being in perfect condition, but that was cracked nevertheless.

Having suggested some convenient and rapid continuity tests, let us pause for the present and consider our general chart of troubles, and see if a simple procedure can be devised to be followed in the great majority of cases to locate the trouble. A localized evil is over 50 per cent. cured. For simplicity, we are giving a method which covers most radio ailments in tabular form. Where the remedy is obvious it is not mentioned.

There are two general cases of troubles; one by defect and the other by excess.

Trouble Chart II

(I) By defect: No signal or weak signals are heard.
(II) By excess: Other sounds besides signal, such as hum, interference from other apparatus, etc., are present.

(I) (a) No Signals.

1. Tubes light.	a. If speaker O.K. tap tubes gently. b. If speaker is "dead," try continuity tests or examine speaker for mechanical trouble.	If sound is heard in speaker try continuity tests (1) (2) or (3).
2. Tubes don't burn properly.	a. A.C. Line open b. Broken "A" wires. c. Fuse burned out. d. "A" battery dead.	Check "A" voltage with voltmeter, or short circuit leads momentarily, if no voltmeter is at hand. Observe spark or its absence.

(I) (b) Weak Signals.

1. Bad tubes.	a. Replace them by new ones or at least interchange them in the set, if possible. This may be advised before going to inspect set. b. Some tubes may be reactivated. Run set without "B" voltage for a few minutes, and then after re-setting "B" voltage, observe strength of signal.	
2. Tubes O.K.	a. Speaker circuit broken.	Try test No. 3.
	b. Speaker defective mechanically.	Adjust air gap, center cone, tighten clamping screw.
	c. Measure voltages, starting from power stage backwards.	Antenna too short, or partially shielded.
	d. Examine antenna connections.	
	e. Look for non-simultaneous tuning of set R.F. system.	

(II) Interfering Sounds.

1. Intermittent Operation and Irregular Noises.	a. Disconnect antenna, ground or both. b. Examine and test speaker leads and connections. Wiggle gently all leads, especially to A, B, & C sources. c. Short circuit plates and grids to filaments through large condenser starting from power stage backwards to localize bad contacts, if possible. Set should go "dead" while the short circuiting condenser is across.
2. Unmusical but Continuous Sounds.	a. Uncouple aerial and turn full volume. b. Detune set from any carrier wave and run with little or no r.f. amplification. c. Examine ground circuits. d. Investigate surroundings to find sparking devices or other sources of shock excitation. e. Examine rectifiers in the set and be sure that they do not produce shock excitation, or if they do, that proper condensers are used to eliminate its propagation. f. Install adequate filters in the line connection to set, or in the offending electrical devices.
3. Musical Tones.	*A.* Frequencies equal to, or multiples of a.c. supply. a. From insufficient filteration in eliminators. Use head phones to localize. b. If tubes are fed by a.c. reset mid-point of potentiometers. c. Be sure that there is the required voltages in all tubes, especially the "C." d. To localize hum, short circuit grids and plates to ground by means of large condenser.

(Continued)	e. Shunt the field of dynamic speaker with high capacity condenser, if fed from low tension rectifier.	
	B. Other musical tones of constant pitch.	
	a. Add filtering condensers or coils or both in d.c. lines.	
	b. Remove induction from a.c. leads by separating them from set, especially from the detector.	
	c. Change angle of audio transformers to avoid induction from leakage field of power transformers. Move set away from eliminator.	
	C. Variable pitch sounds.	
	a. r.f. regeneration.	Adjust balancing condensers. Reduce "B" voltage. Check grid resistors.
3. Musical Tones	b. a.f. regeneration.	Separate speaker leads from set. Put resistance or condenser across one of the audio transformers. Put larger by-pass capacity across "B" supply. Re-design audio system of return circuits.
	c. Acoustic-electric regeneration.	Move speaker away from set. Use "howl" caps on one or more tubes. Reduce audio amplification by means of resistance across one or more stages.
	d. "Motor Boating."	Use large condensers or resistance or "glow tube" across "B" supply. In resistance-capacity-coupled amplifiers, use smaller condensers or lower resistance grid leaks. The product R.C. should be .005 for good reproduction.

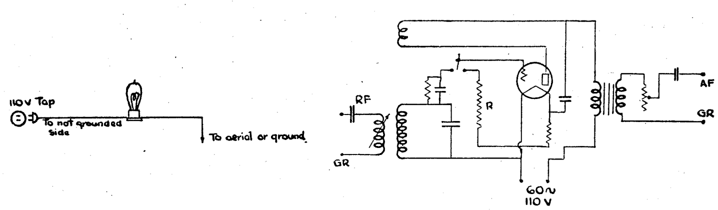


Fig. 6

The table of remedies for the most common troubles in a radio set is not exhaustive; such a thing is almost impossible. There are, however, some special situations which it is well to mention. One of them is the case of sets catching fire or blowing the fuses. In the first category the most common fault is due to poor dielectrics in the filter condensers or bad insulation in the eliminator wiring. In such case the easiest way to make the continuity tests would be to connect a 50- or 75-watt lamp in series with the socket line and turn on the radio set, See Fig. 7. By gradually disconnecting or unsoldering the condensers from the positive end of the eliminator network it is possible to find out quickly which condenser or condensers are short circuited. Before attempting to unsolder any connections it may be advisable to take the rectifier tubes out of their sockets and see if the short circuit still manifests itself by the lamp burning rather bright; in most cases the lamp will go very dim as soon as the rectifiers are out

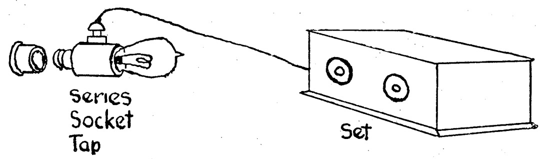


Fig. 7

of the circuit, and it will be evidence enough to warrant searching for short circuited condensers. Sometimes the buffer condensers that are connected across the high tension secondary of the "B" voltage transformer may have been short circuited, and in that case the lamp will still burn rather brightly when the rectifiers are out of their sockets. In very rare instances short circuits develop in the windings of the supply transformer, as the manufacturers usually make them fool-proof and with generous rating, but if the condensers get short circuited and the power is kept on until something catches fire or starts smoking, the transformer ought to be examined for breakdowns and for open circuits in the windings and replaced, if found defective.

In some d.c. sets, the fuses in the house go off when the ground or aerial of the set is not protected by an insulating or "blocking" condenser. The filament lead of a set must be at ground potential for r.f. and a.f. voltages, but may be at over 100 volts difference of potential with respect to the grounding system, usually the steam or water piping. For this reason, the condensers in series with the antenna and with the ground ought to be of sufficient dielectric strength to stand 120 volts continuously and considerably more on account of surges. The operation or attempt to operate a d.c. set from a.c. mains does not result in blown fuses, but an a.c. set connected to a d.c. line will ordinarily blow the fuses or will get its power transformer well burned out. If the transformer has a series resistance to control the voltage at the primary, the resistor will be the first to burn out and will ordinarily save the transformer, therefore, it is well to look for the open at the resistor first.

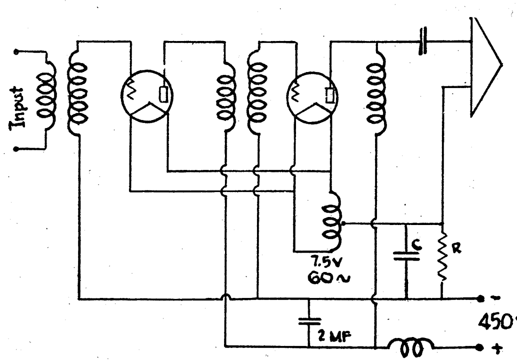


Fig. 8

SOME CASE-HISTORIES

Part III. Let us now exemplify what has been said previously with typical illustrations taken from actual cases.

Example No. 1. A set was built with a very fine audio system and fed a 36-inch W. E. cone. It contained originally resistance-coupling in the audio system but was re-built with excellent transformers instead. The first audio tube was fed like all others except the power tube, by storage battery. The owner decided to have the first audio operated by a.c. and leave the detector operated by a single dry cell and thereby dispense with the storage battery altogether. A UX-210 was used for first audio and the same type of tube for power. When the substitution took place, the fine bass tones were gone, but the middle register and the treble suffered but little change. What was the reason? The way to proceed, of course, was to check the voltages at all the tubes after making sure that all the tubes were fresh. At all points the voltages were what they were expected to be. So long as the treble tones were the same as before, there was no indication of open circuits or shorts. The speaker was not touched and looked to be in good condition; therefore, there was a suggestion of interference in the passage of the low tones. The principles discussed in connection with audio regeneration, Fig. 2, threw some light, and after examining the return circuits of the audio system, the cause was discovered. Both power tubes had a common "C" battery resistance R shunted by the condenser C, Fig. 8, of insufficient capacity, with the result that there was negative regeneration for the lower frequencies. An 8 mfd. condenser was added in multiple with the one 2 mfd. unit in the set and the quality came back as good as before.

Example No. 2. A set at the writer's house was terribly microphonic; the slightest vibration would start a howl. No question of the speaker being too close, as it was in an adjacent room. Moreover, the pitch of the microphoning howl changed. The tubes were gently tapped, and at times not so gently when the patience was somewhat exhausted, and the howl increased or diminished at the good pleasure of the set. According to the method outlined in the table, it was plainly a case of acoustic-electric regeneration. Later on it was found that although this phenomenon was present to a certain extent, even at the great distance between the set and the speaker, there was also a peculiar case of "motor boating" present at the same time, making the investigation more difficult. To separate the two phenomena, head phones were used and yet the howl would come in not of a sudden, but sometimes after a few minutes of operation, gradually increasing in intensity. To localize the trouble, according to our methods we proceeded to isolate the interference starting from the power tube end, and we moved the head phones to the first audio stage. The howl persisted. The power tube was put out and the howl still persisted. At that moment and a good turn of luck, the leads feeding the filaments of the 231-D tubes in series, got short circuited and the tubes went out, but the "B" voltage was kept on, and so was the howl!! With every filament out, the howl kept going on! The answer was to be found

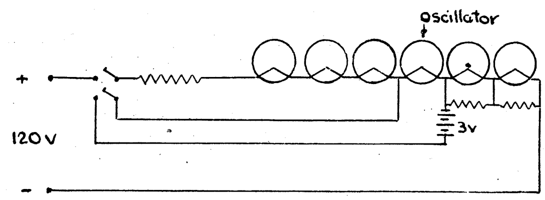


Fig. 9

in the action of the glow tube voltage regulator under certain conditions as an oscillator. This property has been used as timing device by some engineers in connection with cathode ray oscillographs to get time abscissæ. The removal of the glow tube or the addition of a very large electrolytic condenser eliminated the trouble.

Example No. 3. A case of intermittent operation, just like fading, but with strong local signals occurred with a superheterodyne of the Radiola 25 type adapted for operation from the d.c. mains of the Edison Company. The set had been operating just as badly from an aerial loosely coupled to a tuning coil or from the loop. The voltage fluctuations of the line could not explain the fading, because with a good d.c. meter the line was found not to vary more than one volt above or below 120 for a given period of say half an hour. This change would mean about $\frac{1}{40}$ or a volt in 3 volts across the filaments of the UX-199 tubes. However, it was necessary to observe very closely the connection of the variations in signal strength with the line voltage. It was found that when the set was freshly tuned the higher voltages corresponded to the weakest signal, and the reverse may happen when re-tuning the set. This gave considerable light on the cause; higher voltages sometimes reduce the signal, sometimes they increase the signal; why? The intermediate frequency amplifier had a very sharp band filter effect, and therefore if the local oscillator changed in frequency by a very small amount, the signal would fade accordingly. To prevent the local oscillator from changing frequency the voltages on the tube should be very constant. It was found that the "B" did not have anywhere near as much effect on the frequency as the "A" and therefore, the 3 volts across the filament must be maintained very constant. To effect this, a small "C" battery consisting of the usual three dry cells was connected across the filament, as shown in Fig. 9. A double pole switch made it possible to turn on the battery only when the line was turned on, so that the battery acts only as voltage regulator and furnished only a very small current to the tube as the line voltage changes. That fixed the set against fading.

Example No. 4. A Neutrodyne set with five 201 tubes wired with their filaments in series and supplied from a power pack with "A," "B," and "C" voltage was found to give an intolerable noise similar to a circular saw in a carpenter shop whenever the three dials were tuned to the same wavelength. If there happened to be a carrier wave in the air of the same wavelength to which the dials were adjusted, the noise became much louder. It seemed to contain a fundamental tone of 120 cycles with a host of harmonics and roaring sounds.

Upon detuning, there was a considerable diminution of the interfering noises and also the harmonics and the "saw mill" effect almost faded away, leaving a fainter 120 cycle tone with possibly 240 cycles besides. For anybody possessing musical instincts, it was plainly a case of a.c. hum with transients superimposed. To make sure, the set was operated from direct current sources (in this instance from the d.c. mains of the laboratory) and then starting the power pack with the "A" leads short circuited so that the current would be furnished through the resistance network. The noise did not come in even when the dials were tuned to the same frequency. This showed plainly that it was not a case of radiation. Then the "A" wire was touched to the negative filament terminal of the set while operating from d.c. and then the noise came in with moderate intensity. After trying all the possible grounding combinations nothing seemed to avail much, except perhaps grounding the negative end of the filament circuit through a condenser to a radiator, and the negative "A-" terminal of the power pack to a water tap. Apparently the transient current which came from the power pack produced a drop of potential in the leads going to the ground and this affected the r.f. system. As a trial, a tuned circuit consisting of a coil and a condenser was inserted in series with the ground wire coming from the power pack. The moment that the tuned circuit was adjusted to the frequency to which the dials were tuned, the interference disappeared. In cases of transients it is very difficult to lay down a general remedy, but the use of series inductors and shunt condensers to the ground or combinations of both offer the means for their elimination. In the particular instance mentioned, the power pack had no buffer condensers across the high tension secondary, and as "S" tubes were used for rectification, and the current starts very suddenly and stops just as abruptly every half wave, shock excitation of the r.f. tuned circuits occur, and hence the 120 cycle tone with all kinds of harmonics will come in as soon as all the dials are adjusted to the same wavelength. The installation of the buffer condensers fixed the trouble. In another similar set, the substitution of the "S" tubes by thermionic rectifiers proved satisfactory.

Example No. 5. A battery set worked very well where it was made but when taken to its destination would hardly speak except with Station WHN which was very near. All the connections were carefully checked; moreover, other sets worked well at the place where the set under examination was to be used. There was no question of tubes being old, or of insufficient antenna or ground connections as other sets worked at that place at the same time. The "B" voltages were measured and were right, and so were the other voltages. The short circuiting test for continuity of the audio system showed very small gain per stage, in other words the clicks were not much louder at the detector grid than at the first audio or power stage grids, but they seemed to follow the expected loudness increase toward the detector in quality but not in quantity. The "A" voltage was right at the battery terminals and as a matter of assurance, it was tested at the tube sockets and then the "C" voltage at the

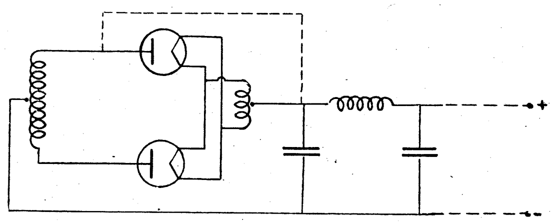


Fig. 10

detector was tried and here the error was discovered, the detector grid circuit showed no positive bias. Immediately the bias on the first audio (which in that set was zero as it employed no "C" battery in the first audio) was found positive. This showed that the "A" battery was reversed. So it was and the mistake occurred because the plus mark on the rubber top of the binding post was partly rubbed out giving an impression that it was a dash or minus sign. The other post had no mark at all!

Example No. 6. A curious case of short circuit in a power pack, hard to diagnose over the telephone but easily found upon inspection, occurred recently. The set was operating very well. The power pack contained two '50 tubes and two '81 rectifiers, one of which went red hot all of a sudden and the music stopped. The other one showed no signs of trouble. My first advice was to remove both rectifiers and see whether the filaments of the '50 tubes burned with approximately normal brilliancy, to ascertain whether a short circuit in the filter condensers was responsible. This done, it was found that they burned with a little less than normal brilliancy. Then one rectifier was put on at a time, and the right hand side tube would make no difference whether it was on or off, but as soon as the left hand side tube was inserted, it would get red hot and the filaments would go dimmer. With this information, I started to draw diagrams while on my way to the scene of the trouble and decided that it was not a case of filter condensers short circuited. Upon inspection I found the high voltage wire connecting the beginning of the filter passed very near one of the posts of the high tension winding of the power transformer, and when tubes were changed or the box was opened and something added to the equipment, the wire got closer to the post till it touched it, the insulation broke through, and one of the rectifiers was receiving 1200 volts across its elements while the other one had them short circuited, as can easily be seen from Fig. 10.

In conclusion, let us repeat that the first thing to look for is bad tubes, bad connections, wrong connections, and insufficient or improper voltages. Always make sure of the obvious things and take absolutely nothing for granted. Ordinarily troubles are caused by the most silly things; for lack of using ordinary common sense in the operation or installation of radios. Defective apparatus are found in cheap sets and in cases where first cost economy have been the first and preponderant considerations.

Notes of the Club Membership

These notes add much, we feel, to the club for our membership is large and scattered and only through contacts such as this can all the membership be informed of the activities of all. Send in a few words about what you are doing to the Club Notes Editor care Club Headquarters.

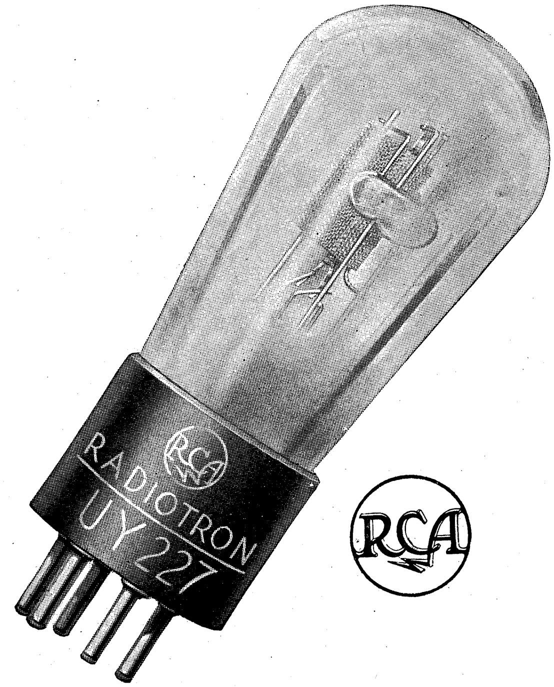
Alfred Dowd may now be reached at Box 207, St. John's College, Annapolis, Md. He has been visiting NSS and NAA.

G. R. Entwistle of Wollaston, Mass., formerly Radio Editor of the Boston Herald Traveler for three years, is now President of the Massachusetts Radio and Telegraph School. He has been a licensed commercial radio operator for 18 years.

Dr. George Seibt, of Berlin-Schoneberg, Hauptstrasse 11, is the internationally known German radio engineer and manufacturer of radio apparatus and accessories. His firm specializes in measuring instruments for radio technology.

W. N. Weeden has been working for the Western Electric Company at 195 Broadway, New York, on special radio, loud speaker, and hearing aids sales engineering problems. He is leaving shortly for the West Coast where he intends to engage in recording work for Electrical Research Products, Inc.

Willis Kingsley Wing is editing RADIO BROADCAST at Garden City where he reports the sun shines often enough and the Doubleday Doran gardens are swell in the summer. He is now living in Garden City, having removed from Forest Hills which was too full of real radio luminaries.



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