RADIO SERVICING MADE EASY

LEONARD C. LANE

VOLUME 2

radio servicing made easy

LEONARD C. LANE

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How to Fix Transistor Radios and Printed Circuits
New Shortcuts to TV Servicing

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To my Father, a gentle

and peaceful man.

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VOLUME 2

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Troubleshooting Charts

Introduction

WELCOME to the ranks of those who want to earn more by servicing radio receivers.

We could let you jump right in with both feet, give you a complete circuit of a radio receiver and say: "Here. Do this and that . . . and the set will be fixed." That's a cook-book method. A few technicians might think that's good, but what do you do when the chief cook is out . . . and you have a collection of sets with troubles not described in the book?

With our approach you'll be able to look any radio set right in the face and say, "See here. No nonsense out of you or else . . ." What's more, you'll really mean it.

For many years radio service technicians fixed nothing but radios. There were all sorts of radios. Big ones. Little ones. Sets with 15 tubes. Sets with one tube.

But then, along came television and radio took a back seat. Practically all radio receivers were of the 4 or 5-tube ac–dc-type. If you could fix one, you could fix them all. Television was the big thing. People weren't too anxious to spend any money fixing their little sets since they were so cheap to begin with.

People have now become accustomed to television. Many homes have two television sets. And then people discovered radio all over again, after the novelty of television wore off. There is a big demand for radio again.

What sort of radio? All sorts! Clock radios, personal portable radios, short-wave receivers, marine radio receivers, police and airplane receivers, console receivers for the home, FM receivers for the home, FM receivers for use in automobiles. Just in the automobile alone, we have, in addition to AM and FM types, sets that fit into the dashboard, sets that fit into the glove compartment, sets that fit onto the rear-view mirror, sets that fasten to the floorboard (in sports cars).

Radio receivers now come in all shapes and sizes. Some are so tiny that they fit into a vest pocket—or will, just as soon as vests come back into style. Most come equipped with a hearing aid type of earphone so you can walk down the street listening to your favorite program.

And some sets are so big that they need a large console cabinet to hold them.

What does all this mean to you? Just this. These sets are going to break down—get out of order. The time to learn how to fix these sets is now—not when the set is sitting on your bench with the customer breathing down the back of your neck.

The day of the old "know one—know them all" is gone. Today we have such a large variety, that you can't "pick up your servicing knowledge as you go along."

Here is one cheerful note. In many cases, if you study one particular circuit, you will find it used in a number of sets, all of which look different. Just as an example, consider a transistor if stage. You will find it in personal portables, in home receivers, in auto radios. There will be some differences but many similarities. You won't find a *completely* new if stage with every new type of receiver.

We hope we haven't painted too dark a picture for you. We're just anxious that you should be fully prepared. Troubleshooting techniques learned here can be used on any electronic circuit. A dead stage will give the same wrong indications in a radio as in an amplifier. Noise interference must be traced with the same procedures and instruments in an automobile radio or an industrial installation. Once the principles are understood the solutions will come much easier.

Just one last word. We have tried to make this book as readable as possible, but that doesn't mean that you should consider it as a novel. By all means, read both Volumes 1 and 2, and read them often. But keep them around as reference books. The troubleshooting charts were prepared especially to help you. Take advantage of them.

LEONARD C. LANE

CHAPTER 6 AM receivers

WHAT DOES AM mean? It all depends on where you are and what sort of job you hold. If you are in bed and your alarm clock starts hammering away at about 6 in the morning, then you know that AM means any hour before noon.

If you are a radio service technician you know that AM also means amplitude modulation. But what is amplitude modulation? Amplitude modulation means that we change the height or the strength (or the amplitude) of the carrier with an audio signal. A receiver that can tune in such a signal (and use it) is known as an AM receiver. Just as we can load a truck by hand or by machine, so too can we put an audio signal on a carrier in different ways.

The AM frequency range

Look at a map and you will see all sorts of roads shown on it. Some are super-highways, turnpikes and freeways. Then we have two- or four-lane highways, gravel roads and some roads that don't even deserve the name.

We have roads through the air, used by radio waves. We can't see these roads, but the space through which these waves travel has been divided just as surely and as definitely as the roads on the ground. Of course, we don't call them air roads or anything like that. Instead we call them bands.

Thus, we have television bands, short-wave bands, bands for marine radio communications, Citizens radio bands, etc. But the one we are interested in now is the broadcast band. This band covers the frequency range from 540 to 1600 kilocycles. All stations in this band are AM stations.

The power supply

How far do you think we would get if we tried to take a ride in a car with an empty gasoline tank? And just as gasoline supplies the power to move a car, so too must we have a unit in the receiver to get lazy electrons into motion. That unit is our power supply.

For transistor radios the power supply is a battery. For vacuum-tube receivers, the power supply begins outside the receiver at the power outlet. But outlets supply ac and our tubes need dc. Not only that, but seldom does an outlet furnish the correct amount of voltage for our tubes. It's either too much or too little, so we must do something about changing that also.

Fig. 601 shows the basic elements of a power supply. Let's see what we have. The two block diagrams cover practically every

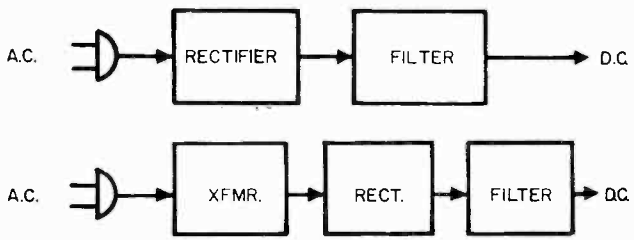


Fig. 601. *Two basic types of power supplies. Some power supplies have a transformer; others do not.*

type of power supply you will have in servicing AM receivers. The only difference between them is that one of them uses a power transformer.

AC–DC power supplies

The supply that does not use a power transformer is called ac-dc. This means that it will work from outlets that deliver dc or ac. The fact that practically all power today is ac (when did you last see a dc power outlet?) makes no difference.

The filament circuit

Did you ever join in a game called "snap-the-whip"? The players (on skates), hold hands and, as they travel faster and faster, some of them get "pushed" forward at pretty good speeds, but when this happens the line or the connection between players is broken.

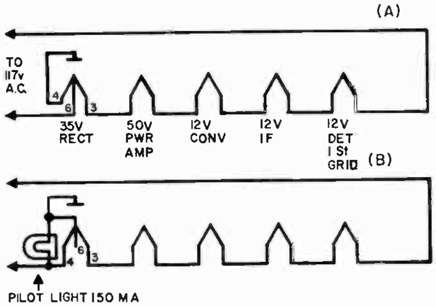
This game reminds us of the filament circuit shown in Fig. 602.

The filaments are connected in series. But if one of the filaments opens, then none of them can work, since they are then all out of the game.

Troubleshooting the filament circuit

If all the tubes are lit, then you know the filament circuit is not open and no troubleshooting is needed. Remember, though, just because a tube lights does not mean the rest of the tube is good.

Fig. 602. *Two typical filament circuits. In ac-dc sets the filaments are connected in series. Some older sets use a pilot light connected across one half of the filament.*



But what if none of the tubes light? How do we know which one of the tubes is in trouble?

We have several ways of finding out. Use whichever one of these methods you prefer.

1. Test all the tubes in a tube tester. This is slow, but you might also locate some tubes that are weak, intermittent or open.
2. Remove each tube and check each filament for continuity with an ohmmeter. This method can be used if you don't have a tube tester and don't want to bother removing the chassis from its cabinet.
3. For this next method you will need to take the set out of its cabinet, but in most modern sets you can do this very easily and quickly. Set your vom or vtvm to read ac volts. The range switch should be set so that full-scale deflection is more than 125 volts. Connect the test leads (Fig. 603) across each set of filament pins, in turn. (For this test the line cord must be plugged into the outlet and the receiver switch turned on.) If you get no voltage reading, the tube you are checking has a good filament. When you measure across a tube's filament pins and you read the full line voltage, remove the tube. Its filament is more open than a baby's mouth at feeding time.

4. Tube-substitution method. Some service technicians keep a set of tubes on hand. These tubes (known to be in perfect condition) are their "test tubes" and are never sold or used for any other purpose. The tubes are substituted for those in the set, one at a time, until the defective tube is found.
5. You can use a neon-tester. This inexpensive unit can be bought in radio parts stores or hardware stores. Just put the test leads across the filament terminals of each tube. When the neon bulb lights, you have the tube with the open filament.

Make a continuity tester

You can make your own tester using a porcelain socket, a 10-watt bulb, some wire and a pair of alligator clips as shown in Fig. 604-A. Use the tester in the same way as the neon tester described above.

Another continuity tester you can make is illustrated in Fig. 604-B. Insert a 10-watt bulb in a porcelain socket. Put the bulb in series between an outlet and the power line. To test any ac-dc

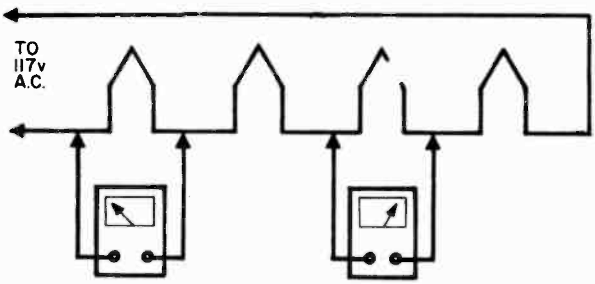


Fig. 603. *Ac voltmeter method of locating an open filament. If the filament is good, the meter will read zero. If the filament is open, the meter will give a reading.*

set, plug it into the bench outlet instead of directly into the power line. If the bulb lights, you know that the tube filament circuit is unbroken. Of course, if the bulb doesn't light, you must still check through the receiver, using any one of the methods we have described so far.

Whichever servicing system you use depends on you. No method is best, since they all have disadvantages and advantages. The best one is the one you like the best.

In some older sets you will find a pilot light connected across two of the filament pins of the rectifier. Normally, the pilot light causes no trouble, but this doesn't mean that it can't. If the light flickers, you may have poor contact between the light and its socket. This can produce noise in the receiver, aside from the fact that a flickering light is annoying. If the set has a pilot light (but the light isn't working) replace the bulb. If a circuit is wired for a pilot lamp it must be used. Without the lamp in the circuit excessive current will soon burn out that portion of the rectifier tube filament.

Other filament troubles

Don't jump to the conclusion that the set has a defective tube if the tube filaments don't light. The trouble might be in the outlet.

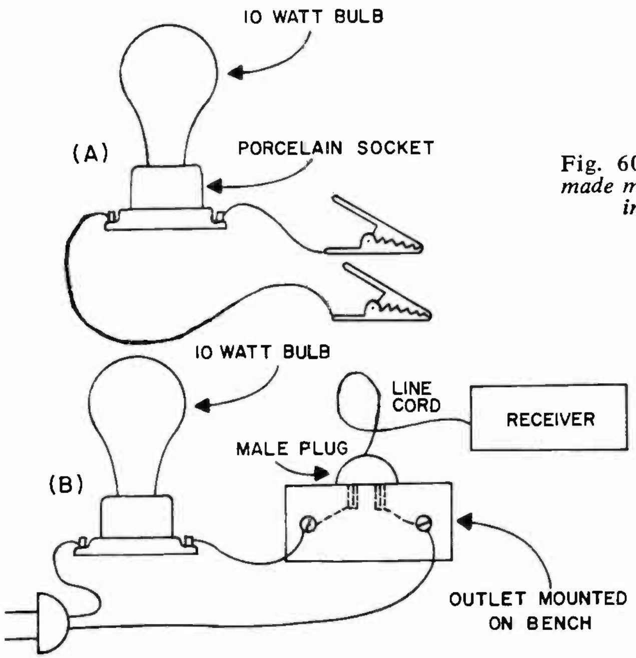


Fig. 604. *Some homemade methods for checking filaments.*

The quickest and easiest test is to connect a lamp or use a neon-lamp tester. Even if this shows power at the outlet, don't take it for granted. The contacts in the outlet may be spread, or else the male plug on the line cord may have its prongs pushed apart.

Check the interlock (Fig. 605). It may not be making contact. If you have any suspicion that line voltage isn't getting into the set, check with your vom or vtvm. Set the meter to read ac volts (on a high enough range) and check the two leads going to the interlock on the chassis side. If you have voltage here, then the outlet, line cord and interlock are good. If you do not have voltage, the trouble is in the interlock, line cord, male plug or outlet. Also consider the possibility that the house fuse may be open.

The rectifier and filter

Do you know the old saying "One man's meat is another man's poison"? It applies, after a fashion, to radio sets also. The line

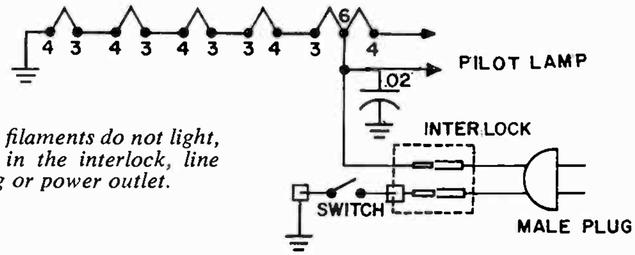


Fig. 605. *If the tube filaments do not light, the trouble can be in the interlock, line cord, male plug or power outlet.*

voltage is good enough for lighting electric light bulbs, heating toasters and running vacuum cleaners, but not quite satisfactory (as is) for radios.

How do we make the change from ac to dc? Just as easy as can be. We use a rectifier tube. This tube allows current to flow through

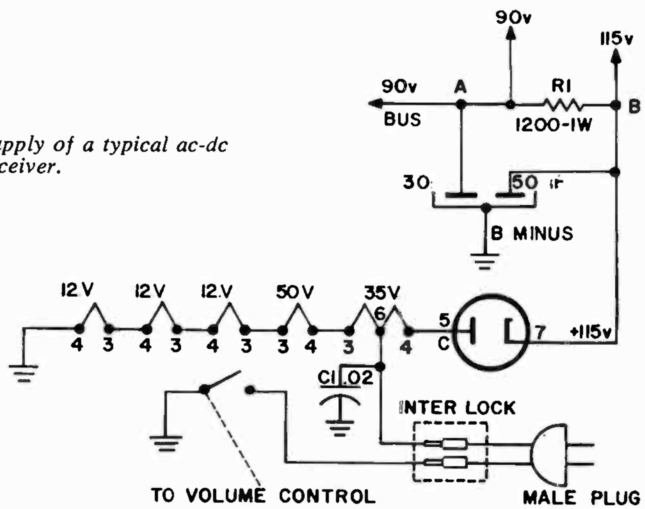


Fig. 606. *Power supply of a typical ac-dc receiver.*

it in only one direction. The result isn't pure dc but with the help of a filter, we get a voltage that's smooth enough for our tubes.

The way in which we do this is shown in Fig. 606. The input to the tube is ac. The output is dc. Now as we test the supply we will learn what sort of troubles to expect.

To check B-plus voltage, set your vtvm or vom on the dc scale with the range selector set to read about 200 volts full scale. Connect the negative test lead to B minus. Touch the test lead to point A in Fig. 606. You should read about 90 to 125 volts.

If you get no voltage at point A, move over to point B. If there is a voltage reading here, then you have found the trouble. Resistor R1 is open. If you get no voltage at point B, set the meter to read 200 to 300 ac volts and touch point C. If you get a voltage reading

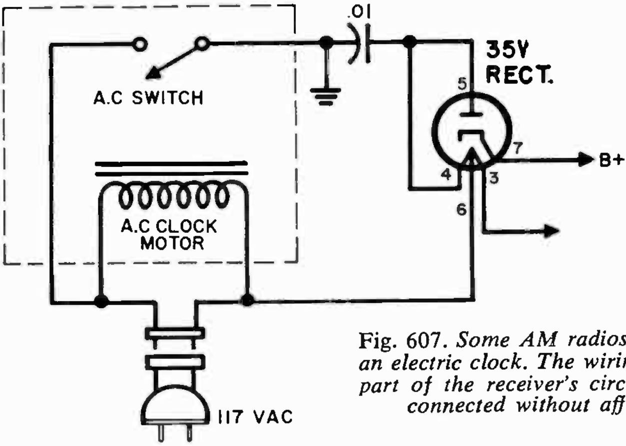


Fig. 607. *Some AM radios come equipped with an electric clock. The wiring of the clock is not part of the receiver's circuits and can be disconnected without affecting the radio.*

here, try a new rectifier tube since this test shows it isn't working.

If the filament of the rectifier tube isn't lit, don't bother with voltage tests since there will be no voltage.

What other troubles can we have? Suppose we go through our check list.

Troubles in the Ac-Dc Supply.	**And What To Do About Them.**
Filaments do not light.	Make sure trouble is not in line cord, interlock, male plug or outlet. House fuse may be open. Receiver on–off switch may be defective. One or more tubes may have open filaments.
No B-plus voltage. Filaments light.	Open filter resistor or defective rectifier tube.
Hum. B-plus voltage is lower than specified on manufacturer's schematic.	Try a new tube. Rectifier emission may be too low. Check the filter capacitors. Shunt these capacitors (one at a time) with a known good unit. Watch polarity. Use capacitors having same (or higher) voltage rating. If hum disappears and voltage goes up, capacitor in set is defective.

Hum (Continued)	If one capacitor in a block of two becomes defective, you may get leakage between the two capacitors.
Strong hum.	Can be caused by heater-to-cathode leakage in any one of the tubes. Not always possible to detect with tube tester. Try tube substitution.
When station is tuned in, set begins to hum.	Reverse line plug in socket. Disconnect line filter capacitor (C1 in Fig. 606). If hum disappears, replace unit with a new capacitor.

Other troubles

In some sets the power supply of the ac–dc set is tied in with other units, such as an electric clock or a turntable. A set may have

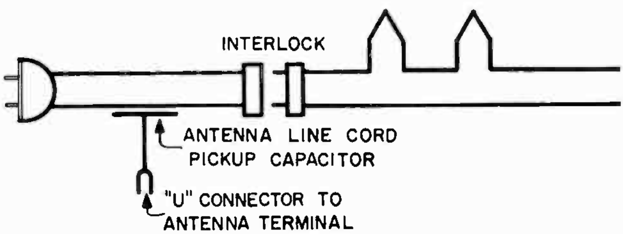


Fig. 608. *If the receiver uses the power line as an antenna, try reversing the power-line plug if you have a hum problem. Removing the U-connector from the antenna terminal may help.*

a turntable with the signal from the pickup playing through the audio amplifier of the receiver. If the receiver has a bad hum when the turntable is used, try replacing the line filter capacitor. This is usually .01 to .02 μf. Try a capacitor having a value of .05 μf. You may have to go as high as 0.1 μf, but use the smallest value of capacitance that will eliminate the hum.

Does the set have a clock? If so, the clock is always connected across the ac line and is independent of the on–off switch in the receiver. If, for some reason, the clock becomes defective and cannot be repaired or replaced, disconnect the clock's ac leads. The connections are simple, as shown in Fig. 607.

Some sets use the power line as an antenna. Fig. 608 shows how this is done. Metal is wrapped around one side of the line inside the set. There is no physical connection between the metal and the copper wire of the line cord, but there is a small amount of capacitance. Not much capacitance is needed. The power line acts as an antenna and transfers the signal to the antenna coil in the receiver.

Sometimes this connection produces hum or noise. To check, remove the U-connector from the antenna terminal on the receiver. If it has no effect, replace the connector. If it eliminates the hum, keep the connector removed or else replace it and try reversing the line plug in the outlet. Sometimes this is helpful.

Semiconductor rectifiers

Some sets use a semiconductor diode in place of a rectifier tube. What sort of troubles can we expect? Just about the same as in the power supplies we have studied so far.

There is less of a voltage drop across a metallic rectifier than across a tube and so the B-plus voltage on the cathode side of the rectifier will be about 140 v. (Fig. 609.)

Most of the rectifiers in table radios are rated at 100 ma. Never replace with a unit having a lower rating. The same rating or a higher one is acceptable.

Semiconductor rectifiers (like tubes) give their highest voltage

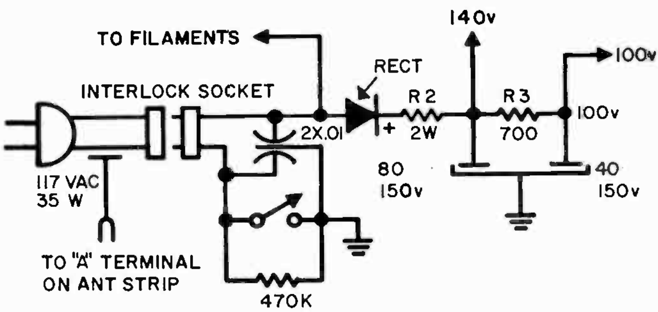


Fig. 609. *Semiconductor units are often used in place of rectifier tubes.*

output when they are new. The voltage gradually drops off with use. If the set sounds weak (or not as peppy as it should), check the voltage on the cathode side of the rectifier. If the voltage is down 15% or more, replace the rectifier. Your clue to the fact that the diode has seen its best days is when the set stops playing when a heavy-current drain appliance is plugged in.

If you suspect the rectifier, shunt it with a known good unit. You won't need to remove the old one or to unsolder its leads. If, after doing this, you note an improvement in the set's operation, replace the rectifier. If the set has a history of poor operation and the diode needs too frequent replacement, use one having a higher current rating.

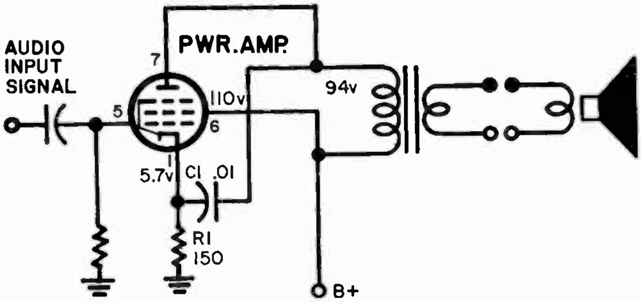


Fig. 612. *Typical circuit of an audio power amplifier in an ac-dc receiver.*

	You should read the resistance of transformer primary. If not, check the fuse (if any) interlock, line cord, line plug and on–off switch.
	Sniff transformer and see if you can detect odor of burning. If you can, transformer winding is shorted.
No B-plus output. Rectifier lights.	Try new rectifier tube. If rectifier tube has whitish deposit on inside of glass, near the base, or has a bright blue or purple glow when power is turned on, tube is gassy and must be replaced. If rectifier plates glow red, input filter capacitor is shorted.
	If rectifier plates glow red and filter resistor (of filter choke) starts to smoke, output filter capacitor is shorted.
	Make sure rectifier tube is seated well in its socket.
	Check filter resistor or filter choke for open.
Set hums.	Shunt filter capacitors in the set with known good units. Watch polarity. Use capacitors with an adequate voltage rating.
	If the filter capacitor is multiple unit in one can or container, there may be leakage from one capacitor to another.
Set plays, then stops.	Some rectifier tubes have a cathode. Set playing, then stopping, is often caused by short from heater to cathode. Replace the tube. This condition also happens if cathode emission is on borderline of being good and line voltage drops. Could be caused by heavy-current-drain appliance being turned on, especially in older homes whose line wiring wasn't intended for modern, heavy-current appliances.

Motorboating.	Check filter capacitors—especially output filter unit. Check decoupling resistors and capacitors. Although these are not usually shown as part of the power supply, they are really added filtering units.
Set sounds very weak. Some stations cannot be picked up.	Weak rectifier tube.

We've put in quite a bit of time on power supplies for the very good reason that power supplies can and do keep us busy. But what about the rest of the set? Let's follow our usual practice, start at the speaker end of the receiver and work our way back to the front end.

Is there any advantage to this method? Perhaps not from a servicing viewpoint, but we do it this way to make sure that we will not miss any circuit.

How should you service a set? Your first question should be—is the set getting its voltage? If you can answer that question, the next one should be: In which half of the set do we have the trouble? Is the trouble between the antenna and the detector or the detector and the speaker?

Your voltmeter will tell you at once if the power supply is working. Inject an audio signal across the volume control and that will tell you if the audio amplifiers and speaker are working. Note how just a few simple tests narrow the range of search to a few circuits in the receiver.

The power amplifier and speaker

Now that we have a procedure for quick-checking the whole receiver, how do we go about checking it stage by stage?

This is easy. Fig. 612 shows an audio power amplifier. Put your

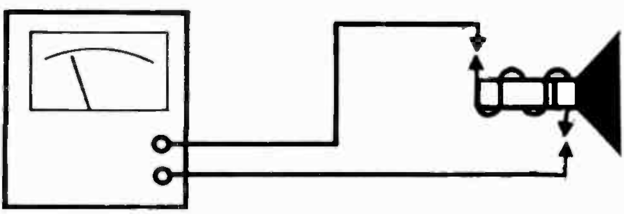


Fig. 613. *How to check a voice coil for an open circuit. Disconnect one lead of voice coil from secondary of output transformer. Rub test leads of an ohmmeter against the voice-coil leads. Scratching noise out of speaker indicates speaker is working.*

audio generator lead on the control grid and listen for the tone out of the speaker. Some service technicians prefer touching the control grid with a finger and listening for the growl or squawk.

This procedure is a good one if you don't accidentally touch the plate (94 volts) or the screen grid 110 volts). The shock may not hurt, but no one ever pulls his fingers away slowly from high B-plus. The chances of whacking your hand against a hard object become very good.

Another method is to click the control grid to chassis with a screwdriver. This method is OK except that you might short the plate or screen accidentally. Some technicians deliberately spark the screen and plate to chassis to see if the tube and the power supply are working. This method can damage tubes and components.

You can also use your soldering iron as a test instrument. Plug in the iron and touch it to the control grid of the audio power amplifier. If the speaker growls, your audio amplifier is working.

Let's ask for trouble

Suppose that the audio power amplifier does not pass the signal, what then? You have the satisfaction of knowing that you have located the defective stage and all you need to do now is to find out which part is loafing on the job.

Speaker troubles

In many receivers the voice-coil leads of the speaker aren't soldered into position but are connected to the secondary of the output transformer with a pair of slide clips. Check them. Have they become loose? Have they slipped out of position?

To test the speaker, disconnect one voice-coil lead from the output transformer secondary and rub your ohmmeter leads across the voice coil connections as shown in Fig. 613. You should hear a scratching noise out of the speaker. Examine the cone. Make sure it has no rips or tears. In time, cones get dry and brittle and fall apart.

Push against the cone gently with your fingers. Can the cone move back and forth without interference? If you feel some sort of obstruction, replace the speaker. Particles that get between the magnet and the voice coil are difficult to remove.

In cheaper-grade speakers, the permanent magnet turns out to be not so permanent. As the magnet gets weaker, the volume out of the speaker will become less. To check, feed an audio signal across the volume control or at the input to the power amplifier, as shown in Fig. 614.

Connect the voice coils of the old speaker and the new one to a double-pole double-throw switch. Switch back and forth from one speaker to the other. If you can hear a definite improvement, replace the old speaker.

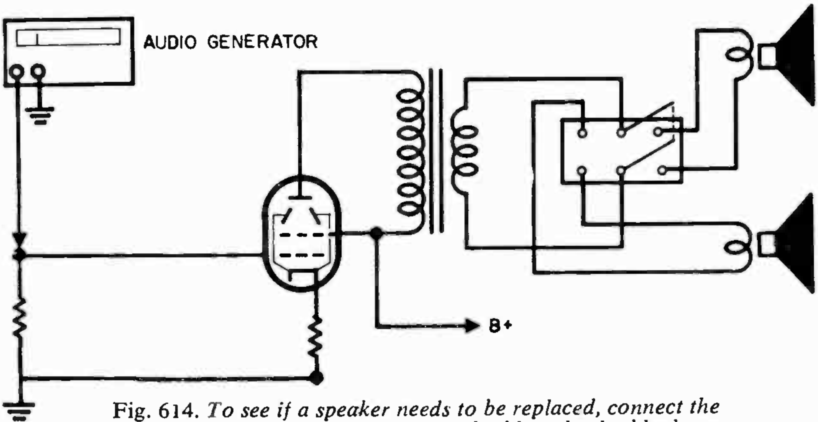


Fig. 614. *To see if a speaker needs to be replaced, connect the old speaker and a new one to a double-pole double-throw switch. Operate the switch and listen carefully. If you can hear a definite improvement, replace the old speaker.*

The speaker is an important radio part, for without it we hear nothing. Let's see what sort of troubles we should watch for.

Troubles in the Speaker.	**And What To Do About Them.**
Distortion	Impedance mismatch between transformer and speaker. In cheap sets the output transformer produces considerable distortion. Replacement with a better unit is helpful.
	The voice coil may be rubbing the pole piece of the magnet.
Oscillation	The voice coil and output transformer secondary are sometimes part of a feed-back circuit. If either the primary or secondary connections should be transposed during replacement of the transformer, the audio amplifier may oscillate. Transpose one pair of leads—not both. See Fig. 615.
Rattling	Poorly centered voice coil. Torn cone. This is sometimes repaired with plastic tape, which gets dry and becomes loose. Spider, used for holding voice coil in position, may have broken or become loose. Spiders are glued into position or held in place with screws. Glue may have become dry or screws may have loosened.

No sound	Open voice coil. Voice-coil lead (or both leads) may be broken, at solder connections.
Distortion	Voice coil rubbing against magnet. As paper cone gets older, it becomes dry. When it gets dry, it shrinks and gets out of shape, pulling the voice coil out of position. If the set uses two speakers, both cones must move out and in at the same time. If not, they are out of phase. To check, connect a dry cell across the secondary of transformers. Do not make a permanent connection. Tap the lead to the dry cell and note movement of the cones. They should both move in the same direction. If not, transpose the connections to one of the speakers (not both). Method of making this test is shown in Fig. 616.

Checking the audio power amplifier

If we put a signal into the audio power amplifier, but get no signal output, our next question is: What do we do now? The

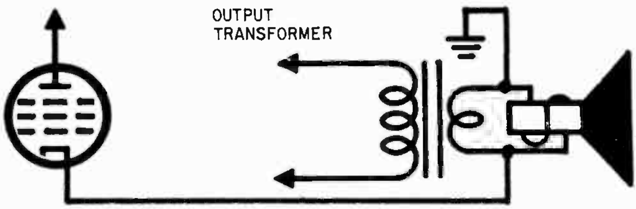


Fig. 615. *Sometimes the voice coil is part of a negative feed-back system. Transposing the ground connection on the voice coil to the wrong side will cause the audio amplifier to oscillate.*

answer is simple. With no audio output, we've located the stage having trouble. Our only job is to find out which part has decided against working.

How do we find out? Take voltage measurements around the tube. Measure the cathode (bias) voltage. If you get no voltage reading, the tube isn't working. Either the tube is defective, or the primary of the audio output transformer is open. Next measure the plate voltage. If you have no plate voltage, the output transformer primary is open. If you have plate voltage, but no screen voltage, then the screen dropping resistor (if one is used) or the connection to B-plus is open.

There should be a small voltage difference between plate and screen with slightly more voltage on the screen than on the plate.

If both voltages are exactly the same, and the tube has no bias resistor voltage, the tube isn't working. Try a new tube.

With a signal tracer and an audio generator (or an rf generator with audio output), you can pinpoint the trouble fairly quickly. Connect the generator to the input (control grid). Touch the lead of the tracer to point A (Fig. 617) and then to point B. If you get a

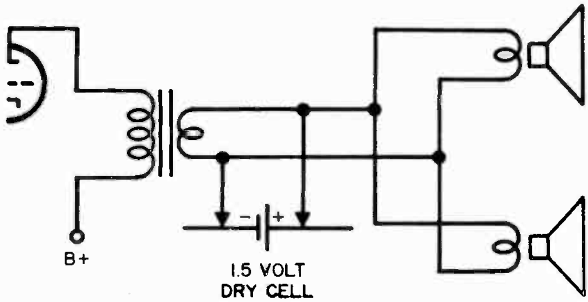


Fig. 616. *Method of checking phasing of speakers. Connect the dry cell. Tap one lead from the secondary winding of the transformer against one terminal of the cell while watching the movement of both cones. The cones should move in or out at the same time. Do not make a permanent connection to the dry cell.*

signal at point A, but no sound out of the speaker, the speaker is defective. If you pick up the signal at point B, but not at point A, the output transformer secondary is defective.

Single-ended amplifier troubles

With Fig. 612 as a guide, let's see what sort of troubles we can expect out of the single-ended audio power amplifier stage.

Troubles in the Audio Power Amplifier.	**And What To Do About Them.**
No sound out of the speaker	Voice coil leads open or voice coil defective.
	Voice coil unable to move. It may have jammed or popped out.
	Defective power amplifier tube. No B-plus voltage.
	Plate capacitor (C1) in Fig. 612, shorted.
	Open in primary or secondary of output transformer.
	No signal from earlier stage.
	Open grid-return resistor.
	Open cathode resistor.

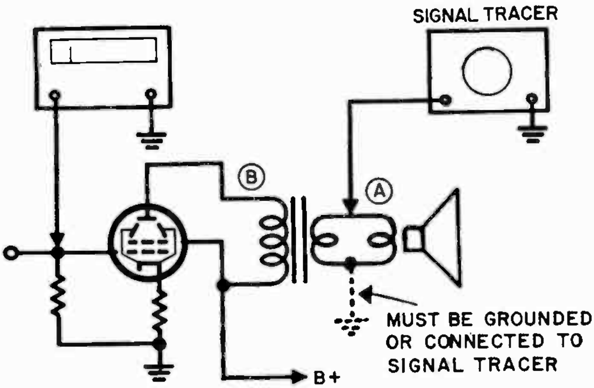


Fig. 617. *Signal-tracing the audio power amplifier stage.*

Sound is weak, may be distorted	Weak tube. Low B-plus voltage. Defective speaker. Changed value of grid-return resistor. Value is too low. Excessive bias. Leaky coupling capacitor connected to control grid.
Distorted sound	Defective tube. Defective speaker. Cathode bypass capacitor (if used) may be excessively leaky or shorted. Extreme condition needed since value of cathode resistor is usually very low. Poor quality output transformer or severe mismatch between transformer and tube. Leaky coupling capacitor connected to control grid. Plate capacitor has partial internal short.
Oscillation	Check feedback network from speaker to earlier stage. Check power supply and decoupling filter capacitors.

The push-pull output stage

Ever watch how trees are cut down? Today power saws are used and they seem to work fine. At one time (still used in some areas) a long saw with handles on both ends was the accepted method. It worked on the theory that two men could do a better job than one.

We have the same idea in radio sets. We use two tubes in push-pull (as shown in Fig. 618) instead of just one. With this circuit and a well designed output transformer, the audio sounds better because it is better. There is much less distortion.

We can't play favorites with the two tubes in Fig. 618. Each tube must receive the same amount of signal voltage. And the dc voltages on all the elements of the tubes must also be the same.

Quick check of the push-pull stage

Do you remember how we checked the single-ended stage? There were quite a number of different tests you could make. You can use all of these on the push-pull stage.

Generally, then, we can service the push-pull stage just as

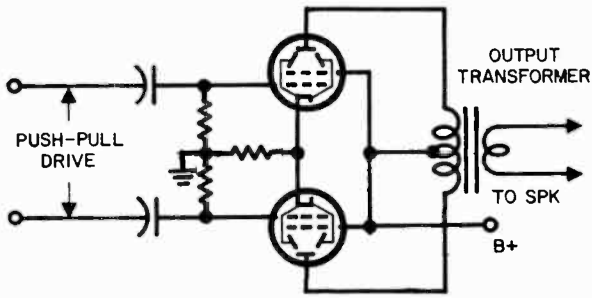


Fig. 618. *A properly designed push-pull stage produces less distortion than a single-ended audio amplifier.*

though it had one tube instead of two. But just to make sure, let's consult the troubleshooting chart.

Troubles in the Push-Pull Output Stage.	And What To Do About Them.
Sound is weak.	One of the tubes may be weak. For best results, use matched tubes.
	Insufficient signal input from driver stage.
	B-plus voltages are too low.
	Push-pull tubes may receive bias from power supply, in addition to cathode bias. Check to make sure bias voltage is correct on both tubes by measuring between control grid and cathode of each tube.

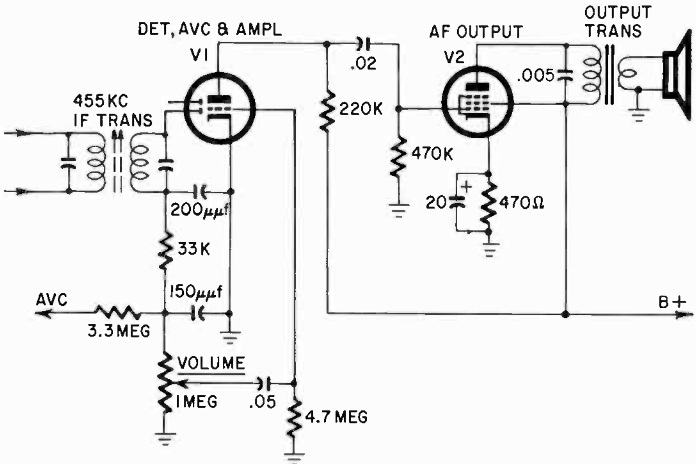


Fig. 619. *Audio amplifier section of a typical AM receiver.*

No sound.	No B-plus voltage. Tubes not in sockets. No signal from driver stage. No filament voltage.
Distortion.	One grid receiving more signal voltage than the other grid. One tube weak, other normal. Improper bias. Original output transformer replaced with unit which does not match impedance of tubes. Input signal is distorted. Leaky coupling capacitor or capacitors to control grids.

Let's move backward

Let's continue our trip from the output end of the AM receiver to the tuner.

What sort of circuit do we have in front of the audio power amplifier? Usually, we have a multipurpose tube acting as a detector, automatic volume control (avc) and first audio amplifier (see Fig. 619).

What is our first question? How can we tell if the circuit is working? Feed in a signal to the control grid of the first audio amplifier and listen to the speaker.

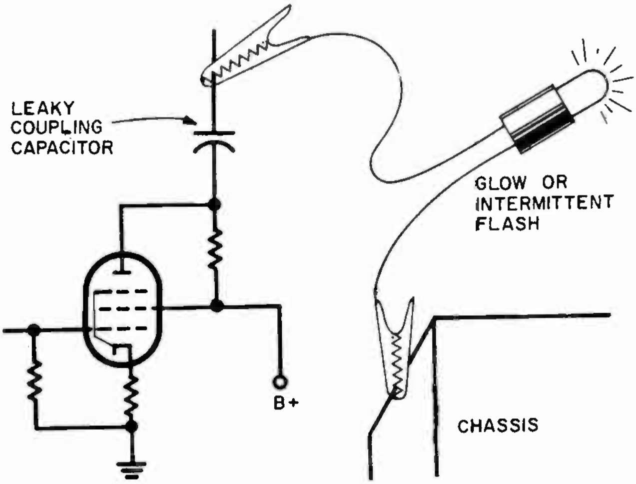


Fig. 620. *A neon lamp can be used to check for leaky coupling capacitors.*

Do you remember all the methods we used for putting a signal into the power amplifier? We can use them here. A convenient place is the volume control. The on-off switch is usually part of this control, so be careful not to touch the switch terminals when the set is plugged in.

Suppose the first audio amplifier will not pass a signal. Our next step would be to examine the check list for the possible causes of trouble.

Troubles in the First Audio Amplifier.	And What To Do About Them.
Signal will not pass through the amplifier.	Tube is defective. No B-plus on tube; the plate resistor is open. Shorted volume control. Open coupling capacitor to control grid. Grid shorted to ground.
Hum	Hum pickup by grid lead. Try moving lead while listening to speaker. Try a new tube. Heater-cathode leakage may have developed.
Intermittent	Defective tube. Check coupling capacitor. Tap lightly and note effect. Volume control may have a worn spot.

Weak sound; possible distortion	Input signal from detector may be distorted. Try another station.
	Plate voltage may be incorrect.
	Check load resistor; also B-plus voltage.
	Coupling capacitor between volume control and grid may be leaky.
	Tube bias may be wrong. Check bias resistor between control grid and ground.
Oscillation	Can be caused by faulty lead dress. Keep plate and grid leads away from each other.
	Stage may be part of feedback network. Make sure feedback winding leads have not been transposed. If feedback resistor is used, check for open or changed value.

Leaky coupling capacitors

Incorrect bias on a tube that is capacitor-coupled to an earlier stage is always reason to suspect the capacitor. If you note that the bias on the tube is much lower than normal, or if the voltage on the control grid is positive, replace the coupling capacitor.

You can use a neon lamp tester, as shown in Fig. 620. Disconnect the lead of the capacitor going to the control grid. Attach the neon tester. If the tester glows steadily, the capacitor is shorted. If the tester flashes on and off, the capacitor is leaky. If the lamp flashes just once (or extremely slowly), the capacitor is in good condition.

The halfway point

On this trip through the AM receiver, we have reached the halfway point. While we have learned about the many troubles that can occur in a radio set, what other fact is just as important? Wouldn't you say that we are developing a method, a system for servicing?

Have you ever watched an inexperienced person working on a set, pushing wires here and there, making tests in no order or sequence. Wouldn't you think that it is better to have a servicing procedure to follow?

What is the detector, and what does it do? It slices the signal in half, much as you would slice a long loaf for making a hero sandwich. The detector is a rectifier, and like any other rectifier, it has a filter. In this case it is used for eliminating the carrier.

Fig. 619 shows our detector and avc circuit. What check can we use? A signal generator is easy and quick. Set the generator to the if of the receiver. Make sure modulation is turned on. Connect the hot lead of the generator to the diode detector plate and listen for the modulated tone out of the speaker.

If this test produces signal output, you know the detector is working. But do not change the setting of the generator, since we are going to need this test instrument for checking the if stages.

Some technicians feel that using a generator isn't fast enough. Perhaps they just don't want to be bothered. We can click test the detector (if the filament is part of a parallel network) by pulling the detector tube out of its socket and then inserting it so that the pins barely make contact. A loud click out of the speaker shows that the tube is working. If it is a series filament set, this must be done before

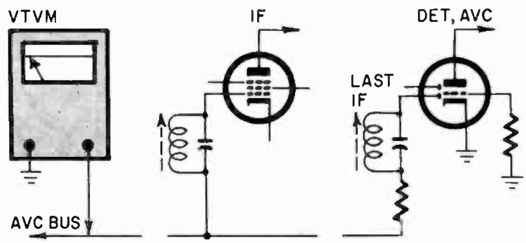


Fig. 621. *A check on the avc voltage will tell you quite a bit about the performance of the if and detector circuit.*

the other filaments get a chance to cool off. This test isn't recommended for series-connected tubes since it is possible to damage the filaments this way.

Most AM tube radios do not use germanium diodes as detectors. Mostly such diodes are found in FM and TV receivers.

Like the other circuits in the set, the detector and avc can have its own share of problems. The check list tells what these are.

Troubles in the Detector and Avc.	And What To Do About Them.
Signal very weak.	Signal from if stage weak. Secondary of if transformer misaligned. Weak detector tube.
No sound.	Check the tube. No signal from if stage. Secondary of if transformer open. Short in if transformer.

Hum. Signals weak or set may not work.	Check avc filter resistor and capacitor.
Sound too loud, no control.	An open volume control element will usually have an abrupt increase in sound level to maximum. If break is at clockwise terminal, there will be no sound.

Checking the avc circuit

A quick way to check the operation of the receiver up to the detector is to measure the avc voltage, as shown in Fig. 621. Connect the probe of your vtvm (set to read minus low volts, dc) to the avc bus and the common to the B-minus bus. Tune in a strong station and note the amount of avc voltage.

If you do this test with the sets you service, and keep a record of the stations, you will soon arrive at some average figure that you can expect for your area. If the avc voltage is lower than normal, the set may be misaligned or it may have weak tubes in the converter, if and detector stages. A lower than normal avc voltage (plus distortion) can also mean trouble in the avc filter.

The what and why of avc

Did you ever see someone sit at a table loaded with all sorts of good things to eat, and refuse to eat more than a small amount? That's self-discipline–not an easy thing to acquire.

Radio receivers have built-in self-discipline. If they get too much of a signal, more than they can digest, they refuse some of it. The circuit in the radio receiver that tells it to be careful about getting overstuffed with too much signal is the automatic volume-control circuit.

If the signal is too large, the avc rectifier develops a large voltage. This voltage is fed to earlier stages in the form of a negative bias. Bias helps keep the gain of a tube down. And the more bias, the less gain.

Of course, the reverse is also true. If the signal is very weak, the automatic volume-control bias is very low, and the tubes which are controlled by this bias have a higher gain.

What is the result of all this? As you tune from station to station, there is less chance of having a very weak sound out of the speaker, only to be followed by a loud blast. Also, if the signal tends to fade in and out a little bit, avc puts a stop to it. All in all, it is a very nice circuit to have . . . as long as it is working the way it should.

The first thing we would like to have for avc is a quick check. How can we tell, without too much trouble, if the avc is in good

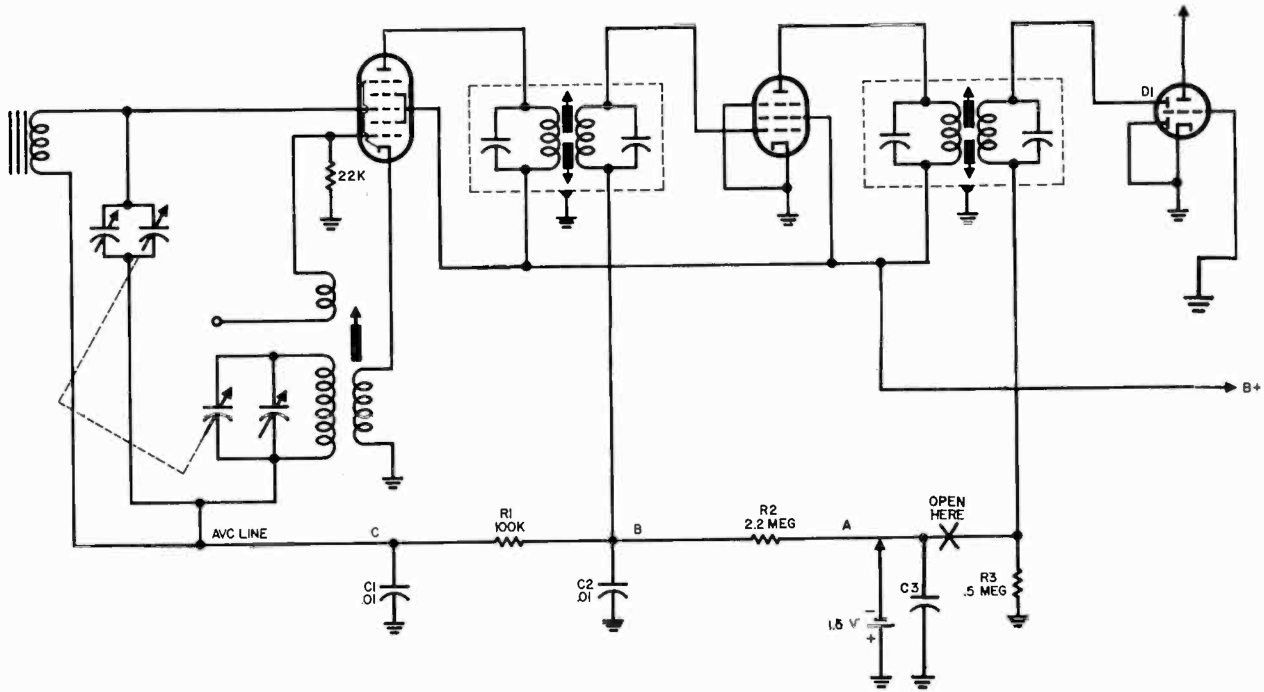


Fig. 622. *The avc circuit can be checked with the help of a battery.*

condition? Here's a simple test. Disconnect the avc bus, as shown in Fig. 622. Tune in a weak signal. Now connect the plus side of a 1.5-volt battery to ground. Attach a wire to the minus terminal of the battery, and then tap points A, B and C one after the other. If you get no improvement at A, but the sound becomes much better at B, check R2, C3 and the volume control. If the sound gets better when you tap at C, check R1, C1 and C2. (In some locations it may be better to us a 3-volt battery.)

Note how simple the avc line really is. We start at diode plate D1, move through the if transformer winding to the volume control. This is near point A. We continue along through R2 to point B. From here a wire goes up as far as the if transformer. The other side of the transformer is connected to the control grid. So this tube is controlled by avc.

Let's move back to point B. Continue along to C, and from there you can find your way easily enough to the grid of the first tube—so that tube is also controlled.

Now try to find the way in which the grids of these two tubes get to ground. You will have to come back, all the way through all the avc resistors and the volume control before you can get to ground.

This is a long journey, but what have we learned? If any resistor (such as R1, R2 or R3) should become open, we would have one (or possibly two) "floating" grids—that is, grids that have no connection to ground.

When this happens, the grids often block the flow of current through the tube and the set either stops playing or does so in a very intermittent way. Using the test battery stops this trouble and pinpoints the difficulty to the avc circuit.

C1 and C2 are avc decoupling capacitors. They provide a path to ground for the rf and if signals, preventing interaction (squealing or constant oscillation) between stages. They also prevent the avc voltage from changing too rapidly.

Isn't is strange that just a few little parts could keep a big radio from working? But this is something that happens all the time. Do you remember the famous poem:

For want of a nail, the shoe was lost
For want of a shoe, the horse was lost,
For want of a horse, the rider was lost,
And for want of a rider, the battle was lost.

Servicing the if stages

Some sea creatures, such as certain crabs, can travel backward very rapidly. This may seem funny to us but, to a crab intent on getting away from danger, it is a very serious matter. We, too, like our friend the crab, have been moving backward—fast, because we have had so much to do. Our backward motion, though, has brought us to the if section.

What is the if? The letters mean intermediate frequency and, when we say if, we are talking about an amplifier.

The if receives the signal from the converter. It amplifies that signal, using one or more stages to do so, and then (possibly with a sigh of relief) turns the signal over to the detector.

Trouble, trouble, nothing but trouble

Should you assume that the correct if is 455 kc? If you do, you may spend quite a lot of time trying to tune the if to a frequency for which it was never designed. If you don't know the if, connect your signal generator to the output of the converter. (We've described this technique before, but it is also applicable here.) Make sure the modulation is turned on. Start at about 200 kilocycles and move up to 500. Somewhere between these two, a strong tone out of the speaker will tell you that you have located the if.

This doesn't always work. The protruding screw of an if slug or the screw of a trimmer might have attracted the attention of a dyed-in-the-wool do-it-yourselfer who promptly turned it all the way. And don't think this hasn't happened or that it can't happen to you.

Now what should you do if no signal comes through? Move the output lead of the generator to the diode detector plate. If you get a signal, move to the primary of the output if transformer. If this produces a signal, transfer the generator lead to the control grid of the last if tube.

In this way, step by step, move toward the converter. Where the if signal disappears do a little more checking and looking.

Of course, not all troubles are clear cut. A single misaligned if, or a corroded connection or a broken slug, inside the transformer where they can't be seen can result in a servicing headache. But please don't reach for that aspirin bottle! At least, not yet. Take a few minutes to go over the if servicing chart. Even if you are a service expert, read the chart since just a single suggestion or idea will be worth the effort.

Troubles in the if.	And What To Do About Them.
Sound weak.	One or more weak tubes. Set might be tuned to a weak station. Check avc bus. Line may be open. One or more if transformers may be misaligned. Check B-plus voltages.
No sound.	One or more tubes defective. No B-plus. No input signal. Open in if transformer. The if stages badly misaligned. Open in avc line. Wrong tube in socket. Shorted trimmer in if. Shorted winding in if. Open grid or cathode lead to if tubes. Shorted screen bypass capacitor.
Intermittent sound.	Check avc components. Examine soldered joints. Make sure no connection is corroded, or loose. Some connections can be very close to each other and short when set vibrates. Slugs or trimmers in if cans may be loose enough to move. Tubes in if stages may be intermittent. Tap tubes lightly while listening to speaker.
Set oscillates.	Some if's will oscillate if you align them too exactly. Detune slightly until oscillation stops. Or, align exactly, and insert 100-ohm 1/2-watt resistor in series with lead to control grid of each if tube. Shield can of if may not be making good contact with B minus or chassis. If tubes have shields, make sure all shields are replaced and that metal makes good ground to ground contact. Screen bypass capacitor may be open. Watch lead dress. Keep plate and grid leads away from each other.

The converter (or mixer and oscillator)

Remember we told you in the introduction that no radio is completely new, that the circuits found in receivers will all have similarities. The converter of the auto radio in Chapter 5 is likely to have the same troubles as the converter in the home radio. The mechanical assembly of the front end will differ. The AM receiver for home operation will normally have a variable capacitor for tuning instead of the more stable, more expensive and less exposed variable inductor tuner found in the auto radio. The end result is the same, circuit operation is the same. The home radio does not rely on an antenna for its signal pickup. This is accomplished by a high-Q ferrite coil tuned to the rf signal of the broadcast station. This is another reason that inductance tuning is not used. The Q of the coil varies considerably when the core is moved in and out.

Rf amplifiers are seldom found in AM broadcast receivers. If a receiver does have one that appears to be troublesome refer to the rf amplifier test techniques of the auto radio in Chapter 5 or to the sections on all-wave and communications receivers in Chapter 9 of this volume.

QUESTIONS

1. Describe two techniques for checking for an open filament in a series-connected filament circuit.
2. The filament of a rectifier tube in an ac-dc set lights, but there is no B-plus voltage at the cathode? What tests should you make?
3. What can you do to minimize the effects of line-voltage transients?
4. What is a power-line antenna? How is it connected? What trouble can it produce? How would you cure it?
5. How would you check a semiconductor rectifier?
6. What quick check can you make to test the entire primary circuit [including plug and line cord] of a power transformer?
7. In making a test, you get voltage at the screen of a power output tube, but not at the plate. What is the trouble?
8. How can you check a pair of speakers for phasing?
9. What troubles in the speaker could cause rattling? Distortion? No sound?
10. How is the output transformer used as part of the negative feedback system?
11. How can you check avc voltage?
12. You have oscillation in a receiver and you have localized this trouble to an if stage. Name two techniques you could use to eliminate the oscillation.

CHAPTER 7

FM receivers

DID YOU ever watch a steamship being loaded? Next time, try to count the different ways in which freight and baggage are put on board. Some of it is carried by hand, some loaded by slings and winches. The freight is pushed, lifted, shoved, tossed, pulled.

In radio broadcasting we have a similar problem. We need to load the signal (voice or music) on the radio-frequency carrier. We have quite a few ways in which to do this. One method is called amplitude modulation which we shorten to AM. Another system is called frequency modulation, more popularly known as FM.

What is the difference between the two? Simply in the method of loading the transport – the carrier. In AM, the amplitude or the height of the carrier is varied. In FM, the frequency of the carrier is varied.

Naturally, since we load the carrier in AM and FM in two different ways, we are going to need two different ways for unloading that carrier. We need to know these differences since it will affect the way in which we service receivers.

Alike—and yet different

The man (or men) who invented the automobile didn't start from scratch. He didn't sit down and say, "Let's throw away everything we know." Instead, he started with a wagon, unhitched the horse and put in an engine instead. With the exception of the horse, early automobiles looked just like wagons.

In the same way, an FM receiver uses many circuits that we see in AM receivers. There are some completely new circuits, but there are also many that (except for the value of the parts) could also be used in AM receivers.

Strike up the band

When we speak of broadcast band, the average person thinks of AM. But we do have another band just for FM transmission. This band extends from 88.1 to 107.9 megacycles, but it is generally referred to as covering the range from 88 to 108 mc.

This gives us our first clue when we start thinking of our servicing problems. Since the FM band is so much higher in frequency than the AM band, our components and parts layout are going to be more critical. We are going to have more of a problem with bandwidth.

Stop that noise

FM has been so widely publicized as being noise-free, static-free and high fidelity that some of us have come to believe it. Repeat something often enough and it sounds true.

FM can be static-free. FM can be noise-free. FM can be made to supply high fidelity. But just because a set is FM does not mean that it has these virtues automatically. There are cheap FM sets just as there are cheap AM sets.

The overall view

To see where we will be going, let's begin with our electronic road map shown in Fig. 701. One difference in these block diagrams is in the detector circuits.

Three types of detectors or demodulators are used. The first one (and the oldest) is the *discriminator*. This type usually has one limiter and sometimes two (in cascade). The *ratio detector* and *gated beam detector* are not as sensitive to amplitude variations as the discriminator, hence do not use limiters. In a few sets, though, you will find a limiter stage used with a ratio detector.

Power supplies in FM sets

What sort of power can we expect in the FM receiver? Think of almost every one you have and you will probably find it. You will have:

1. Transformerless type using a vacuum-tube rectifier.
2. Transformerless type using a semiconductor rectifier.
3. Transformer type with a half-wave supply and using either a semiconductor or vacuum-tube rectifier.
4. Transformer type with full-wave supply and using a vacuum-tube rectifier.

Does this present a problem? Actually, no – or at least, not different from the power supplies we have in other receivers.

Bring on those troubles

In any radio receiver, sooner or later a filament will open. When that happens in a series string, such as that shown in Fig. 702, all the other filaments go along on a sort of sympathy strike and none of them light.

Do you remember that old game called, "Button, button, who's got the button?" That's the sort of a game we play now. Which filament is open? You can't tell just by looking. A very easy way, though, is to use a neon tester. Just connect the tester across each

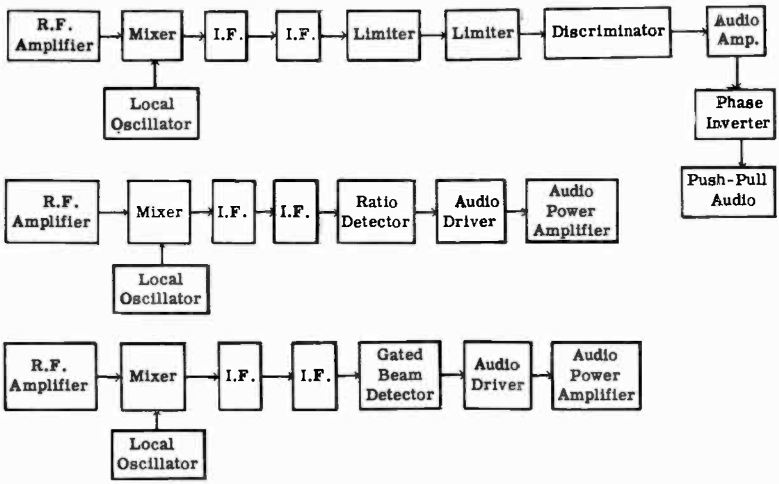


Fig. 701. *FM receivers can use a number of different detector circuits.*

pair of filament pins, in turn. When the neon bulb lights, you have found the tube with the open filament. (This technique, and others, was also described in connection with AM receivers and is covered in Chapter 6.

Which are the filament pins? Be careful! Don't get fooled. They aren't always pins 3 and 4, although these are the pin numbers very often for 7-pin miniature tubes. They could also be pins 4 and 5 for 9-pin types as shown in Fig. 702.

The circuit in Fig. 702 has some interesting features we should investigate. Coming off one side of the power line (connected to L2) is a lead marked LINE ANTENNA. In strong-signal areas a line antenna will do, but an outside antenna, designed for FM, will improve reception on both strong and weak stations. In weak-signal areas, an outside antenna is essential.

Sometimes, all that is wrong with an FM set is the lack of a good outside antenna. The FM signal is there – we should at least meet it halfway.

Note R17, the 1,000-ohm 10-watt resistor. That resistor is in series with the lamp. If the lamp lights (switch closed) you know immediately that you have line voltage on the other side of the interlock. R17 will get warm in operation – that's normal. If you must replace it, keep it away from radio parts that don't like heat, such as wax-filled capacitors, electrolytics.

The rectifier is marked 360 PIV. These letters stand for *Peak Inverse Volts*. This is one of the voltage ratings of the rectifier, so when making a replacement, get one having this value–or higher.

The 82-ohm resistor, R22, helps prevent surges from puncturing the rectifier. If you short this resistor, the set will work just as

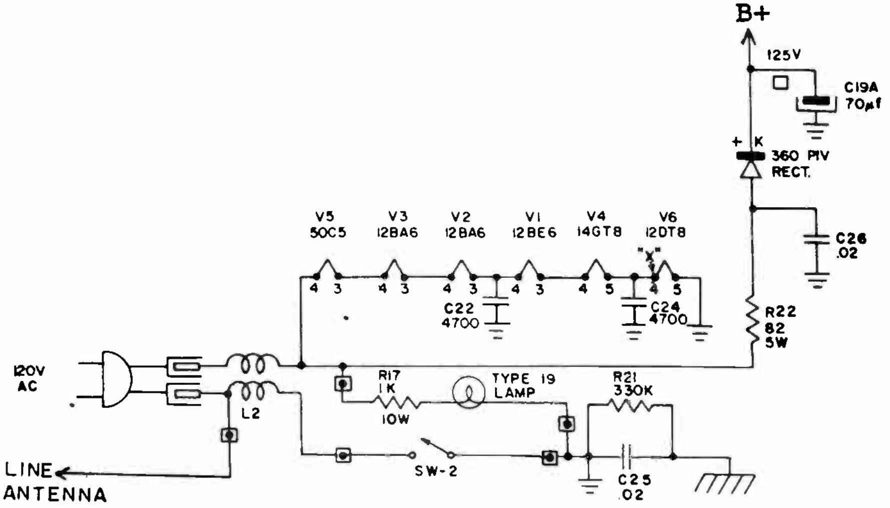


Fig. 702. *Transformerless supply. The series filaments are bypassed by two capacitors. Capacitor C26 protects the rectifier from transient surges in the power line.* (Arvin Industries, Inc.)

well, but sooner or later this current surge of several amperes will damage the rectifier and the input filter. When replacing this resistor, be sure to use a 5-watt unit – or one having a higher rating. If R22 happens to open, the set will lose all B-plus and that will be the end of that.

Where is the B-plus?

Ever travel along a superhighway with a dividing line or barrier between the lanes? Is there any doubt in your mind as to which side you are to travel on? We have the same idea in a power supply. On one side of the rectifier we have ac. And on the other side we have dc.

But where is the dividing line? The cathode and everything beyond the cathode is dc, and everything from the anode (plate) right

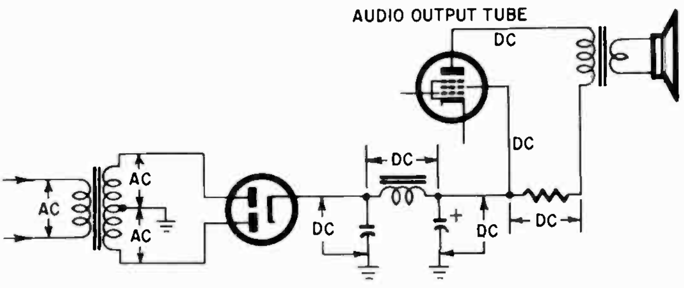


Fig. 703. *Ac and dc voltage points in a power supply. All voltages, starting at the cathode of the rectifier, are dc. All voltages, starting at the rectifier plates and going back to the power line, are ac. The voltage drops across the filter capacitors, the filter choke and the filter resistor are dc. All tube voltages (no signal input) are dc.*

back to the outlet is ac (see Fig. 703). If you keep this in mind, you won't go looking for voltages you can't find.

Make sure you know which is anode and cathode. Fig. 704 shows the symbols for a tube and a semiconductor rectifier.

How do we know whether we have B-plus or not? Start at the screen of the audio output tube. This is generally tied directly into the power supply. If you have no B-plus voltage here, follow the line right back to the cathode of the rectifier. If, at the cathode, you have no B-plus, then your trouble is from the ac line right up to the anode of the rectifier.

Common sense

Common sense is neither so common nor so plentiful as we like to imagine. Obviously, we will have no B-plus if the filament of a rectifier tube does not light. It is true that this results in a condition of no B-plus, but a little thinking will tell us that the trouble may be something more elementary than the B-plus line.

A vom or vtvm is excellent for chasing troubles of this sort. A receiver must have voltage to operate. Start at the power line and follow the connections all the way into the receiver, up to the rectifier, past the rectifier and right up to the tube elements, if necessary. Somewhere along the line you should find an open circuit. It may be a part that is open, a connection that should be soldered but isn't. A break in a printed-circuit-board conductor sometimes will be almost impossible to see. However, if you move the probe of your test instrument along the conductor, you will find the break.

Other troubles

Hum troubles (when caused by the power supply) are generally due to open filter capacitors. If shunting the existing capacitors with equivalent units decreases the hum, replace the filters.

Don't expect electrolytics to last forever. Their capacitance can

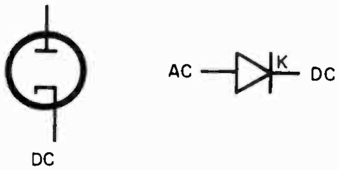


Fig. 704. *Symbols for rectifiers used in power supplies. Up to and including the anode we have ac. From the cathode and beyond it we have dc.*

change, and does change – and not for the better either. Electrolytics will lose capacitance if the receiver isn't used for some time, if they get hot, or if they get old. All electrolytics have a certain amount of leakage. As they get older, the leakage gets worse. (This is like having a hole in your pocket. You can be sure that it's going to keep right on getting bigger.) If not used for a period of time it is possible for the internal structure to break down. It is possible to revive some of these capacitors with a process called *reforming*. This is simply the slow increasing of an applied dc voltage, up to the maximum rating of the unit.

Tubes and semiconductor rectifiers get old, wear out. In a tube the amount of B-plus current depends on filament emission. Remember that the total current of the receiver – and this means the current taken by all the screens and plates in the set – must pass through the rectifier. If the cathode emission of the rectifier is down, the internal resistance of the tube is up and the lower the B-plus voltage will be.

There is a voltage drop across all rectifiers, regardless of whether they are tube, selenium or silicon. When some rectifiers get older, the voltage drop across them increases. The rectifier always gets its share of the voltage first. The other tubes in the set get what is left over.

That's not fair!

Did you ever see kittens that were just born? They know where to get their milk and they know how to get it fast. But before the mother cat can supply any milk, she must first have been fed.

Think of the rectifier as a mother cat and you'll have an idea. In Fig. 705 you can see how all the tubes in the FM circuit are connected in parallel and are a load on the power supply. Naturally, the more tubes we have in parallel, the more current we need. All of this current must flow through the rectifier.

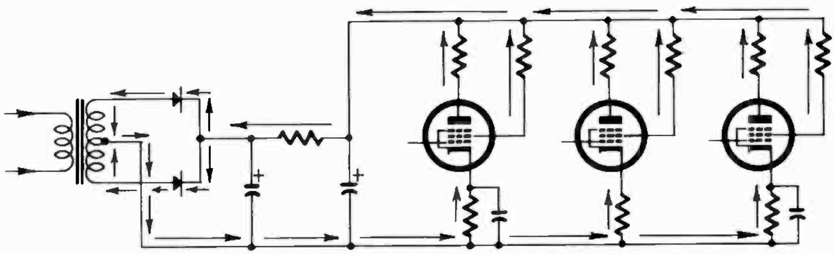


Fig. 705. *The tubes in most circuits are connected in parallel. The current that flows through the tubes must also pass through the rectifier. The more tubes, the heavier the load (that is, the greater the amount of current). As you remove tubes, less current will pass through the rectifier. The arrows show the direction of electron current flow.*

Now you can see why the rectifier is so important. If it becomes damaged in some way (low emission, gassiness), all of the tubes will suffer. The rectifier affects the entire set.

Parallel rectifiers

Sometimes an FM set will have so many tubes that a single rectifier will not be able to pass all the current needed. A pair of rectifiers can be connected in parallel, just as shown in Fig. 706. No arithmetic is needed here. Two rectifiers will pass twice as much current as one, provided they are identical.

Can parallel rectifiers produce trouble? Naturally! Both rectifiers will not get weak at the same time any more than a pair of human twins. And, as one of the rectifiers gets weaker, a strain is put on the remaining good tube. If matters are allowed to continue, both rectifiers will be ready for the junk heap.

Other power supply arrangements

Power supplies are like people. Some are simple. Some are complicated.

In some sets a glance at the series filament might fool us into thinking we have a transformerless type on our hands. But a second look will reveal a transformer connected to the plate of the rectifier. Sometimes the transformer is an isolation type and

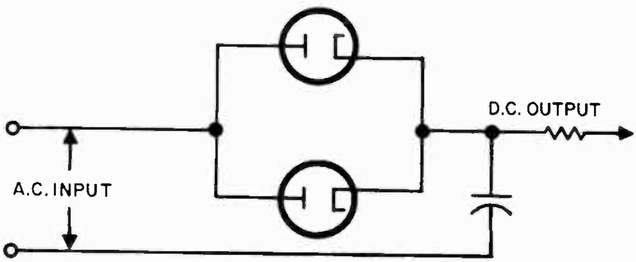


Fig. 706. *Rectifier tubes can be connected in parallel. The trouble here is that the tubes won't wear out at the same rate.*

has a 1-to-1 turns ratio. Since there is no voltage stepup, the plate of the rectifier tube gets the same voltage that it would get in an ac-dc arrangement.

Now take a look at the switching arrangement in Fig. 707. This is needed since this FM set has a record changer and phono amplifier. Which unit will receive the line voltage depends on the setting of the switch. In one position the radio will operate. In the other, the phonograph will work. And there is another position that turns all line voltage off.

Wafer switches of the type shown here (and all other switches as well) can and do have their share of troubles. If the radio doesn't play, but the phono motor works, trouble generally exists in the power supply. If nothing in the set works, then the switch, or line cord or plug or power outlet is out of order.

Wafer-switch troubles

If a wafer switch won't turn readily, don't force it. The switch has two main parts – a movable section called the rotor, and a fixed section called the stator. Sometimes a bit of insulation or a wire gets caught and jams the rotor.

Don't poke into the wafer switch with any tools. The rotor makes sliding contact with the stator and any tool you use will only

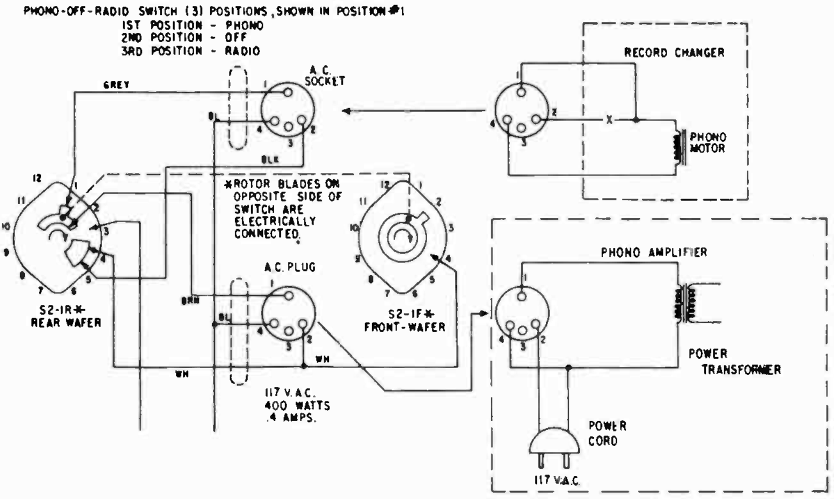


Fig. 707. *Wafer switches can be a source of trouble. In this circuit the wafer switch has three positions and serves three functions. (Shown in position 1.) First position is phono; second, off; third, radio.* (Zenith Radio Corp.)

separate the two, making conditions worse. Examine the switch carefully. If there is any interference (wire, solder) with the rotor, try to remove it.

Since the wafer is exposed, it can get dirty. Commercial cleaner lubricants are available and they do a fine job. When soldering near wafer switches, be careful. Good wafer switches are silver-plated and there is a greater natural attraction between hot solder and the wafer than between a youngster and his favorite TV Western.

Wafer-switch rotors and stators are mounted an insulating wafers of some material such as phenolic. Sometimes these wafers crack. They can also carbonize, causing a short between the lugs mounted on the wafer.

Replacing a section of a multiple wafer switch isn't difficult, but it does take patience. Before making a replacement, tag the leads so you will know where they go on the new wafer. Use a lightweight iron. Generally, these switches solder very easily and do not require strong-arm treatment.

Transformer power supplies

You will find power transformers used much more in FM than in AM receivers. While we have covered this subject in an earlier chapter, there are a few additional points we would like to discuss.

Power transfomer troubles

Power transformers get hot – and the longer the set has been playing, the hotter the transformer will get. Ventilation is very bad in some receivers and so, if the inside of the set seems to work more like a furnace than a radio, perhaps this is normal.

If a transformer has a shorted turn, it will get hot – fast. How, then, will we know if a transformer is hot because of a shorted turn or because it is working to supply the demands of the receiver?

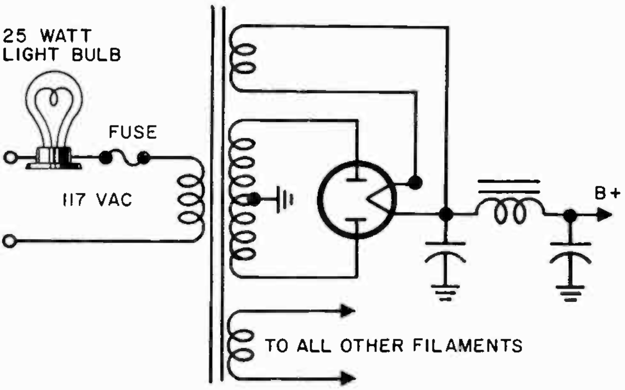


Fig. 708. *Simple test to learn if power transformer has a shorted turn.*

An easy way is to use the method shown in Fig. 708. Remove all the tubes from the chassis. Put a 25-watt bulb in series with one side of the line. If the bulb glows, start looking for a replacement for the transformer.

Naturally, if the fuse keeps popping, or if pitch starts bubbling out of the transformer, don't bother with this test. Sometimes, though, the fuse has a higher rating than it should have, or for some other reason it will not blow. And, if the transformer is generously oversized, it may be able to take a shorted turn in its stride. If you have any suspicions about this, the test in Fig. 708 is worth while.

Audio amplifiers in FM receivers

A merry-go-round is wonderful entertainment. The trouble is the faster it goes, the sooner you get back to where you started.

Sometimes, in servicing work, you may get that same feeling. In an earlier chapter we talked about servicing audio amplifiers, supplied you with a servicing chart, and now we're back at audio amplifiers once again.

There's a very good reason for this. Not all amplifiers are alike. There are enough differences so that we can study new circuits to our advantage.

But is it high fidelity?

There is no reason for an FM set to be high fidelity any more than an AM receiver. Many persons are quite contented with less expensive FM sets but are also just as anxious as any hi-fi enthusiast to keep their sets in good working order.

Thus, not all audio power amplifiers in FM sets are push-pull by any means. A single-ended amplifier does have definite limitations but our chief concern is to keep that amplifier in good operating condition.

One such amplifier is shown in Fig. 709. While it looks like an

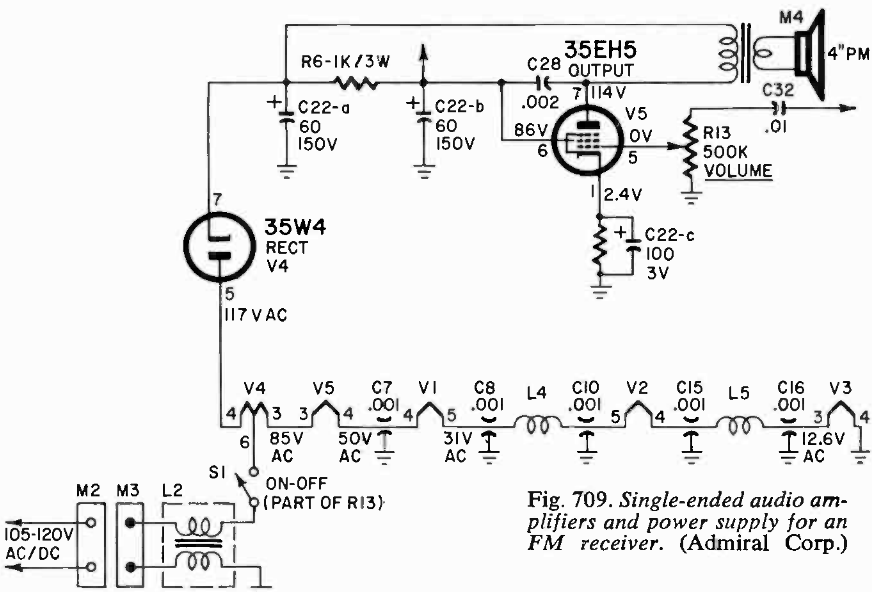


Fig. 709. *Single-ended audio amplifiers and power supply for an FM receiver.* (Admiral Corp.)

ordinary single-ended amplifier, suppose we examine it carefully to see if we can find a few differences.

In other single-ended amplifiers, the screen is usually tied right into the B-plus bus. The plate gets its voltage through the primary of the output transformer. There is a little dc voltage drop across the primary winding, and as a result the plate voltage is slightly less than the screen potential.

Examine the cathode bypass capacitor. The unit is rated at 100 μf at 3 volts. This is quite close to the cathode bias developed across the cathode resistor (2.4 volts). The cathode resistor, 68 ohms, might increase in value. Should this happen, the bias voltage will rise. When the voltage gets high enough, the cathode bypass capacitor will break down.

What does this tell us? In a circuit of this sort, do not replace the cathode bypass capacitor without first making a resistance check across the cathode resistor and a voltage test of the bias.

Now let us look at the control grid. It is marked 0 V. What does this mean? If you will look at the other elements, you will see that they also have voltages marked. All of these are dc voltages and are measured with respect to ground.

This tells us, then, that the dc voltage on the control grid, with respect to ground, is zero. Does this mean we have no bias on the tube? Remember that bias is not measured between grid and ground but between grid and cathode. If you measure from control grid to chassis, the dc voltage will be zero. If you measure from control grid to cathode, the voltage will be 2.4.

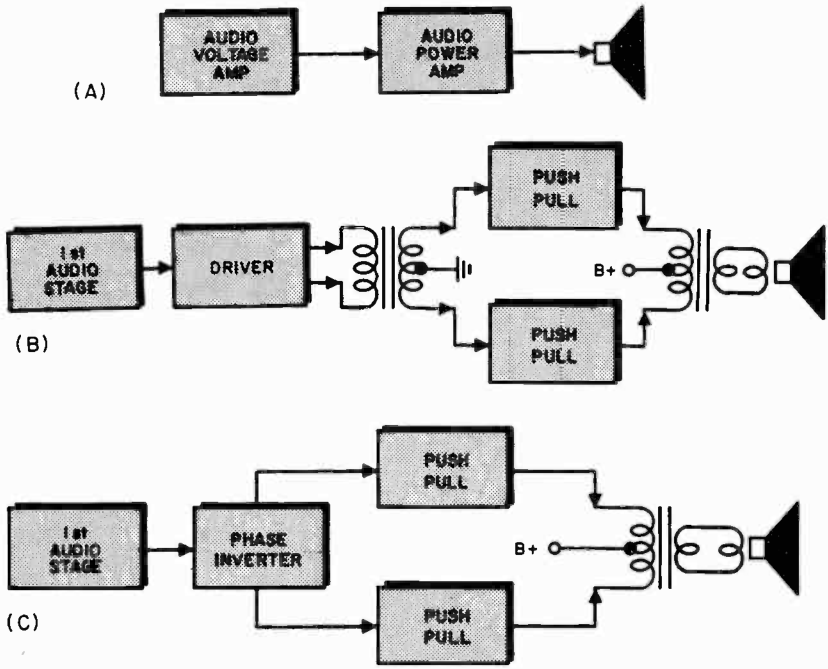


Fig. 710. *Three possible audio circuit arrangements in an FM set. In less expensive receivers the setup is very much like the majority of AM sets. This is shown in (A). In (B) and (C) we have two possible push-pull diagrams. In (B) an interstage transformer is used, while in (C) a phase inverter does the job of the interstage transformer.*

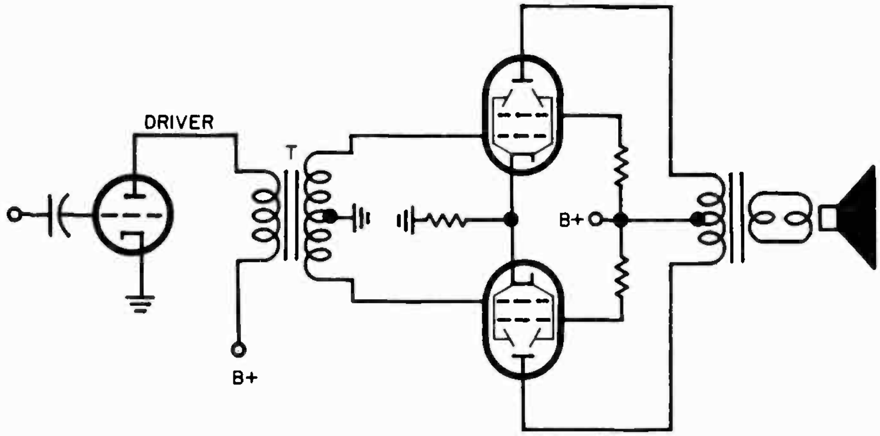


Fig. 711. *Push-pull output stage. Interstage push-pull transformer T couples the driver of the push-pull tubes. Good interstage transformers are expensive, take up room. Most sets use a tube (or a transistor) as a phase inverter to take the place of the transformer.*

Observe the location of the volume control. In AM receivers the volume control is usually placed in the input of the first audio amplifier. Here the volume control is in the control grid circuit of the power amplifier. The volume control also acts as the grid return resistor for this stage.

Servicing the single-ended stage

To service this stage, follow all the directions and suggestions given in an earlier chapter. But is there something more we can do? There definitely is! Note the advantage of having the circuit diagram. We can look for new or unusual circuit arrangements. We can be alert for components that have values that are somewhat different. And we can use the voltages on the schematics as guideposts in servicing.

Push-pull stages

You will find push-pull stages in the more expensive FM receivers. These push-pull stages can be either tube or transistor types. Generally the circuits are identical with those you will find in AM sets. Many sets that are combined AM-FM have push-pull output. No switchover or change is made in the audio circuitry when changing from AM to FM reception.

While the circuitry of the push-pull stage is similar for both AM and FM receivers, you may find some differences in the quality of the parts. In some FM sets the push-pull output transformer is larger and of a better design. If your customer is hi-fi conscious, it would be a good idea, when necessary, to replace the unit with an identical substitute.

For troubleshooting, use the charts and servicing information given earlier. However, you may be asked to service a receiver that has no single component which can be called defective. What you may find is a general reduction of good performance due to aging tubes and parts. Capacitors that have become even slightly leaky can change the amount of bias. Tubes get weaker, reducing gain. Speaker cones get brittle, dry, out of shape. In a case of this sort, what is needed isn't servicing so much as a general overhaul.

The driver stage

The circuitry similarity between an FM receiver and an AM set is strongest in the audio amplifier section of the less expensive receivers. Fig. 710 shows just what we mean. Here we have the block diagram of a first audio amplifier followed by a power amplifier. This is a common arrangement in both types of sets.

In the better type of receiver, both AM and FM, the detector is followed by an audio voltage amplifier, a phase inverter (or a transformer) and push-pull power amplifier.

The phase inverter

What is a phase inverter? Just look at the name and you have the answer. A phase inverter is a stage that inverts the phase and, since we are talking about audio circuits, it is an audio signal that is inverted.

Inverted means upside down. A clown who stands on his head is inverted. He is out of phase with everyone else.

The simplest sort of inverter is a transformer, as shown in Fig. 711. When the signal voltage at the top of the secondary is plus with respect to the center tap, the signal voltage at the bottom is minus. And when the magnetic field around the primary winding changes, so does the polarity of the voltage across the secondary.

The easiest way to understand this action is to think of a see-saw. The center tap on the transformer is like the center of the see-saw. It remains fairly fixed. When one end of the see-saw comes down, the other end goes up. They are out of phase.

We need out-of-phase signal voltages for the control grids of the push-pull output tubes. We can get these out-of-phase voltages by using either a tube or a transformer.

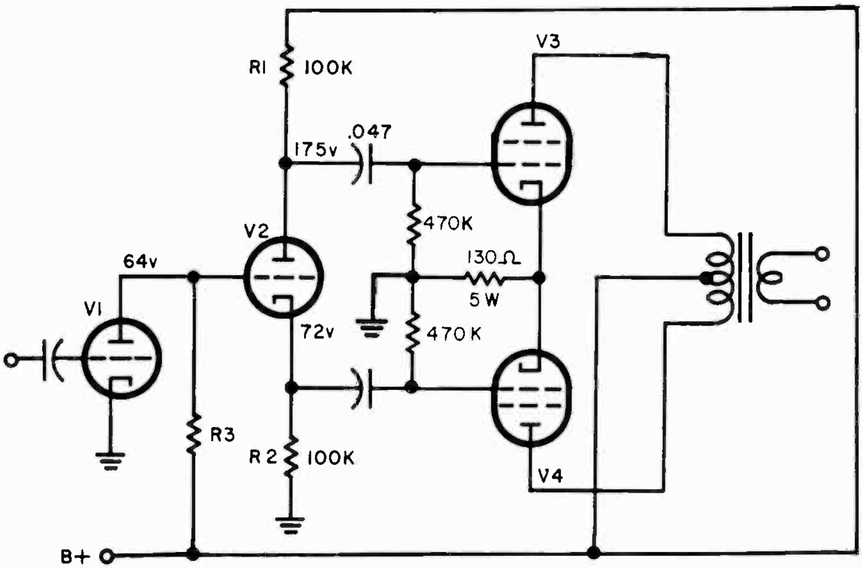


Fig. 712. *The phase splitter. Note that the cathode and plate resistors have equal values. The signal voltage is developed across both resistors and is delivered to the push-pull tubes, V3 and V4, by a pair of coupling capacitors.*

With the inverter stage we get the same servicing troubles that you will find in an ordinary audio amplifier, plus a few more. With the usual audio amplifier, we are happy if we get the correct amount of gain and if the distortion is held within tolerable limits.

When we get to phase inverters and push-pull stages, we can no longer be satisfied with the idea that the circuit is working reasonably well. Unless the phase inverter and push-pull stage give us better audio, higher fidelity audio, there is no use in having a more complicated, more expensive circuit.

There are many types of phase inverters, but the one shown in Fig. 712 is really a phase *splitter*. Like all circuits, it has its share of troubles. Note, first of all, that V1, the preceding audio amplifier, is directly coupled to the phase splitter V2. This means that the plate voltage of V1 and the voltage on the control grid of V2 are the same.

What can we expect to find when we measure the voltage from control grid to ground of V2. 64 volts! This may come as a shock, since we normally do not expect such a high voltage (and positive at that) on the control grid. However, let that be a lesson to us. We have no business measuring from control grid to ground. What were we trying to find anyway? Grid bias? Then we should have been checking between grid and cathode.

R1 is the plate load resistor and R2 the cathode resistor. Both have identical values. Now your first thought might be that identical values of voltage are at the cathode and the plate, since the same current flows through both resistors and both resistors are of the same value.

As soon as we put on our thinking cap, we can see how impossible this would be. If the plate were at the same potential as the cathode, no current would flow through the tube. With the plate at 175 volts and the cathode at 72 volts, the drop across the tube is 175 minus 72, or 103 volts. And if you were to measure the voltage between plate and cathode, this is what you would find. And, if you were to measure the voltage drops by putting your test leads across R1 and then across R2, the voltages should be exactly equal.

What can go wrong?

In an ordinary single-ended audio amplifier, the values of the parts can change quite a bit and the circuit operation would remain passable. But what about our split-load inverter?

The bias on V2 depends on two factors. One of these is resistor R2. R2 acts as a load resistor. The signal voltage developed across R2 is transferred to the grid of V4 through the coupling capacitor. But R2 is also the cathode resistor for V2. What if R2 changes in value? What would happen would depend entirely on how much R2 did change. If its value increased, it would deliver a signal to V4–larger than that delivered by R1 to V3. This would result in distortion. With a higher voltage on the cathode, the bias is larger and would cause V2 to produce distortion. Also, we might not have enough signal developed in the tube to meet the drive requirements of V3 and V4.

Troubles in a circuit of this sort become compounded. It's almost like a dog biting his own tail.

Suppose we remove V1 from its socket. No current would flow through R3. The voltage at the control grid of V2 rises to the full value of the B-plus. This would put a strong positive voltage on the grid of V2 and probably some resistors (R1, R2) would get the bad habit of smoking.

To avoid this possibility, V1 and V2 are put into one envelope, and so, if we remove V1, we also remove V2.

How can we check a stage that seems so delicately balanced. We can do it in several ways. We can make dc voltage measurements and make certain that they are the same as the voltages indicated on the circuit diagram. Or we can feed in an audio signal to the grid of the splitter, and measure the strength of the voltage at the cathode and the plate of the splitter. It should be the same in both cases. But when using your generator, remember the B-plus on the control grid and make certain to have a blocking capacitor in series with the test lead. Your generator may or may not have such a capacitor in its output circuit.

Checking the splitter

We can check the splitter with the help of dc/ac voltage measurements. With no signal input, measure the dc voltages across R1 and R2. These should be fairly equal. Then, set your

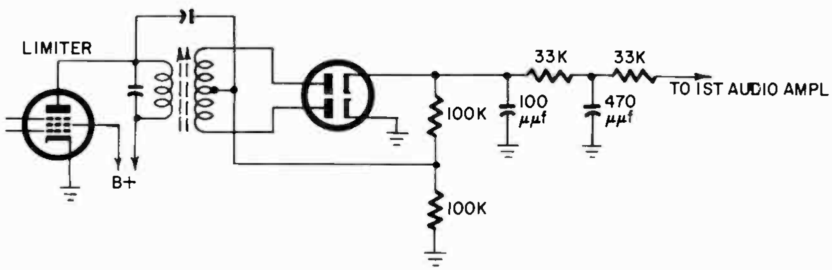


Fig. 713. *The discriminator uses a double-diode as the detector.*

vtvm to read ac volts. Use your generator and feed a steady signal into the splitter. Now, with your vtvm set to read ac volts and with the help of your ac probe, measure the signal voltages across R1 and R2. Once again, the voltages should be equal.

You may come across other types of splitters and inverters, but they should all yield to the same treatment, since they all have the same purpose—to deliver equal but out-of-phase signal voltages to the push-pull amplifier stage.

The detector

If you were a detector and had your choice of circuit, we would strongly recommend that you select an AM set. What an easy life that detector has! All it needs to do is to take the AM signal and slice it in half.

But there is no such soft job for the detector in an FM receiver. Here the detector has work to do! It must change FM variations into an audio signal. Fortunately, we have no shortage of applicants for the position. There are at least three that are used:

1. The discriminator.
2. The ratio detector.
3. The gated-beam detector.

An FM detector is like a politician. You swear by the one you like and you swear at all others. And neither politicians nor FM detectors are perfect, no matter which you choose.

The discriminator

The discriminator circuit was one of the first on the scene and, although it has lost popularity, you will still find it in some FM sets being made today and in many of the older sets.

One of the very nice features of a well-designed FM set is that electrical noise can be minimized or eliminated. Thus, a lightning storm or other undesired noise signal picked up by an antenna will

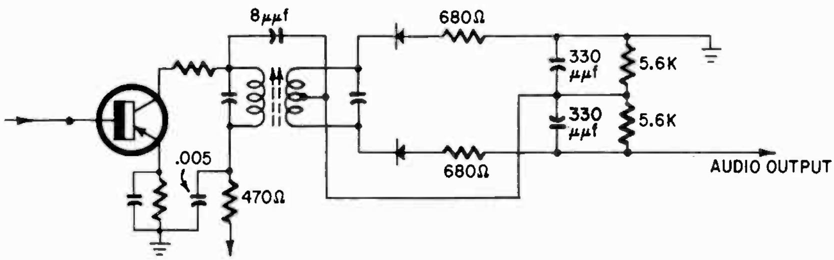


Fig. 714. *In transistor FM, receivers, a pair of crystal diodes, are used in the detector circuit.*

be amplified and heard in an AM set. Noise is AM and just adds to an existing AM signal. The FM receiver, though, responds to frequency modulation, hence the noise is eliminated . . . theoretically.

Not all FM detectors are insensitive to AM. The discriminator is one of these. For this reason the discriminator is usually preceded by one or two limiters. The limiter is designed to saturate easily and clip peaks. And is to a varying signal what a lawn mower is to a lawn that has been neglected for a few weeks. With the help of the mower, the lawn is trimmed and the blades of grass become uniform in height.

With the help of the limiter, any amplitude changes (such as those produced by electrical noise) are clipped.

If you've ever gone to a supermarket to buy olives, you will have learned that they come in three sizes—large, gigantic and colossal.

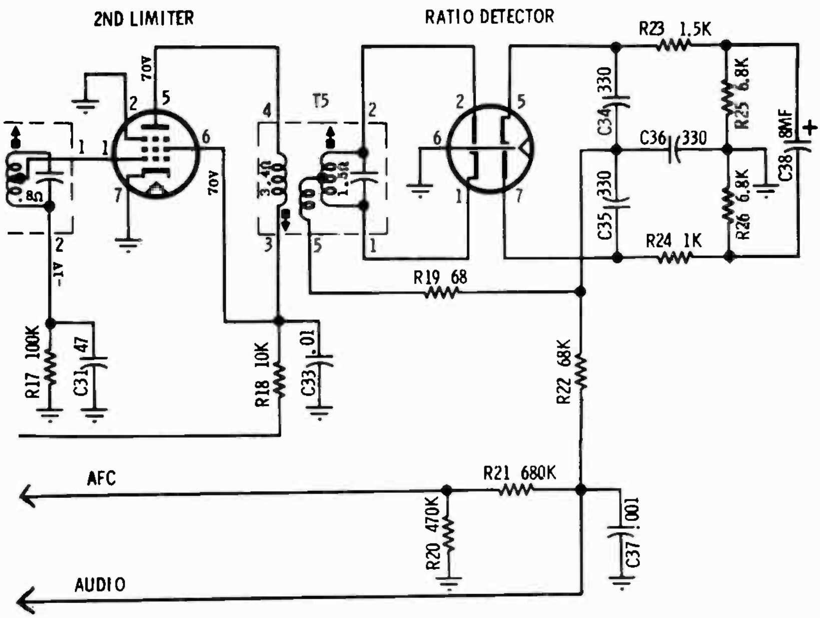


Fig. 715. *The ratio detector does not eliminate AM completely. In some receivers one or two limiters are used ahead of the ratio detector. The detector supplies audio and also automatic frequency control voltage (afc).* (Motorola Consumer Products, Inc.)

We aren't that lucky when it comes to the discriminator. We have only two of those, as shown in Fig. 713 and Fig. 714. We can't even claim that these are different since you can easily see for yourself that the circuits are very much alike. The biggest difference is that we use semiconductor diodes in one and a vacuum tube double-diode in the other.

The ratio detector

The great ambition of every radio manufacturer is to make one tube work where three tubes would ordinarily be required. The discriminator and its assistant, the limiter, requires a minimum of two tubes. The ratio detector, shown in Fig. 715 can usually do without the limiter.

Now you would think that a change of this sort would make every one happy, and ordinarily it would, except for one very small item. The ratio detector does respond to some AM variations and so, in some sets, you will find a limiter still being placed ahead of it. In less expensive sets, though, there is no limiter circuit.

Gated-beam detector

With the discriminator and the ratio detector, circuit designers had to "make-do" with the tubes that were available. This limited the tube and the designer. It's just as though you made a fly swatter out of a rolled-up newspaper. This is fine as a temporary relief but a complete set of screens is much better.

This sort of thinking led to the development of a completely new tube—the gated-beam detector. Designed especially for FM receivers, it is shown in its circuit in Fig. 716.

Here comes trouble

You will note that we haven't explained how these different FM detectors work. It would help to know the theory but this isn't the place for it. We are just interested in learning what sort of trouble to expect with these detectors.

What are the problems that all detectors have? No sound or weak

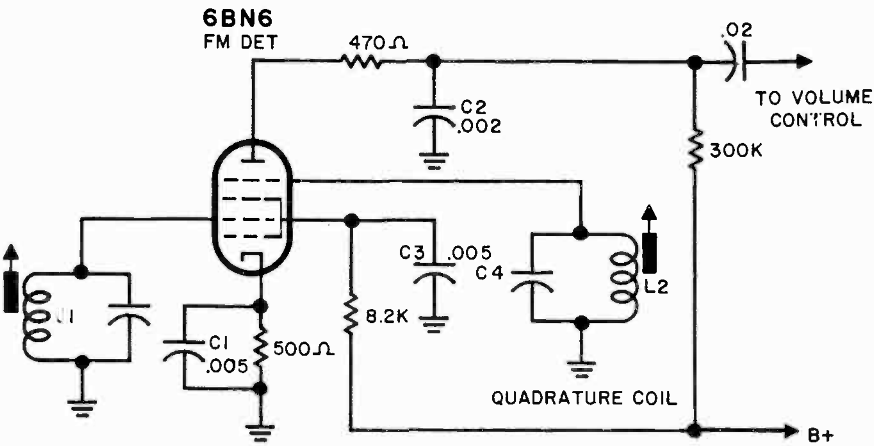


Fig. 716. *Circuit of a gated beam detector. The input is coupled through an if transformer to the preceding stage.*

sound. In most cases the difficulty is caused by the detector tube itself. The easiest check is tube substitution. If the set begins to play when you put in a tube, or the volume is much stronger, then you've found the fault.

But what if tube substitution does not help? What if you have other problems, such as distortion, a high hiss level, poor sensitivity? This is where a check list will come in handy.

Troubles in the Detector Stage.	And What to Do About Them.
Noise.	Substitute new electrolytic (C38 in Fig. 715) across output of ratio detector. Transformer primary or secondary misaligned. This applies to all detector circuits. The transformer might also be intermittent, have poorly soldered connections, missing shield or shield not secure to chassis.
Distortion.	Transformer detuned. Detector tube defective.
No sound, low gain, poor AM rejection.	Replace the detector tube. Check transformer alignment. In the gated-beam detector (Fig. 716), check capacitors C1, C2, C3 and C4. In the same circuit, check L1 and L2 for opens.

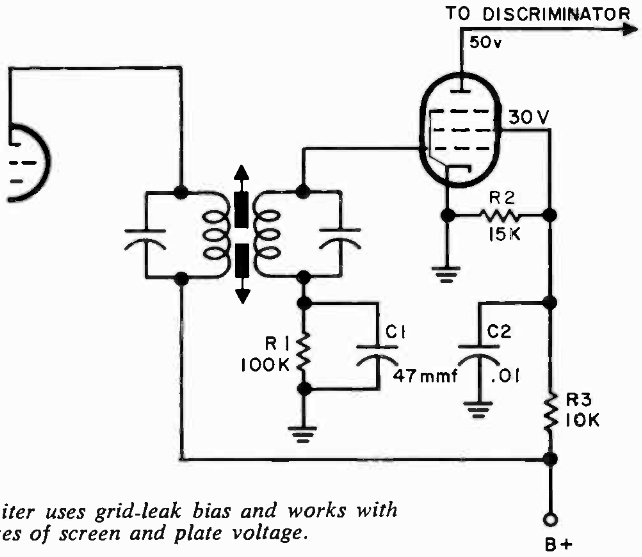


Fig. 717. *The limiter uses grid-leak bias and works with low values of screen and plate voltage.*

Limiters

The limiter is used to remove any amplitude changes in the signal before it reaches the detector. When we say amplitude changes, we mean not only signal voltages but noise voltages as well. Thus, if an FM set is noisy, check the limiter circuit (or circuits).

The limiter (Fig. 717) works with low values of plates and screen voltages. This permits the tube to saturate easily so that the peak current remains the same for weak and strong signals. It is true that this will distort the output waveform, but this doesn't bother us since we are only interested in the frequency changes of the signal, not its amplitude changes.

To make a quick check of the limiter, set your vtvm to read low dc volts and put it across grid-leak resistor R1. Tune in a station. No voltage across R1 indicates trouble in some earlier stage, such as the if or a shorted C1 or if transformer secondary.

Once you have checked for the presence of voltage across R1, move your test leads to the detector diode load resistor, or across the volume control. Presence of audio here will tell you that the signal is passing through the limiter and the detector.

What can go wrong with the limiter

Let's examine the circuit in Fig. 717 and see what can go wrong. C2 is a screen bypass. If it opens, the screen will no longer be at ac (if) ground potential. This means that the screen acting as a plate, will send some signal through R3 to the B-plus supply. From the supply the signal might be fed to some earlier stage to cause oscillation.

If C2 should short, R3 would be right across the B-plus supply. R3 will get hot and will burn out, sooner or later. If, in examining R3, you note that it is quite warm or hot, check C2 before replacing R3. If C2 is shorted, not only will R3 get hot, but the voltage at the screen of the limiter will disappear. Little or no signal will be passed by the tube.

If R2 should short, the effect will be the same as a short in C2.

The limiter can be the cause of distortion. When this happens, replace the tube. If this doesn't help, check the grid leak and its capacitor. Make sure the if transformer isn't detuned. Sometimes inserting a new limiter tube will detune the transformer.

The if stages

If you were to look at the if circuit of an AM set and then at the circuit for an FM set, you would hardly notice the difference. Yet there is one, although we may not be able to see it. This difference is in the frequency of operation.

Why should we care about the frequency? As we go up in frequency, little things become more important. The stray capacitance between a pair of wires in a 455 kc if stage may cause no trouble,

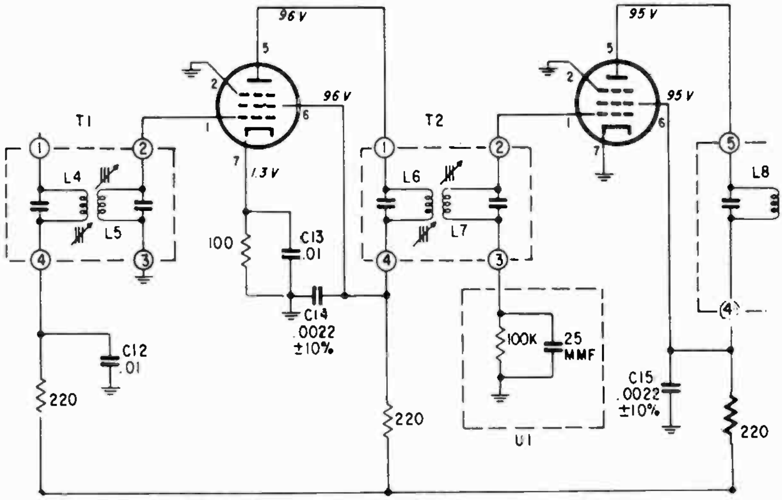


Fig. 718. *If stages in a typical FM receiver. While the second if is not truly an if amplifier it is not completely a limiter either, since the plate and screen voltages are high. Some receivers use two stages like this for limiting, with amplification. The negative portion of the signal is clipped in the first stage, phase reversed in the tube and the positive portion of the signal (now negative) is clipped in the second stage.* (Zenith Radio Corp.)

while the same pair of wires in the 10.7-mc if of an FM receiver could produce oscillation.

First things first

The first thing we want to know is: Does the stage operate. Will it pass a signal? An easy way to find out is to put your vtvm across the limiter grid-leak resistor and tune the receiver to a strong station. A voltage at that point will tell us that the if's are working.

But what if we get no voltage there? All you need do then is to move your test leads back to the grid-leak of the second if. This is the 100,000 ohm resistor (in Fig. 718) shown connected to the secondary of if transformer T2. If you get a voltage indication here, but none at the limiter stage, then the second if stage isn't working. If you get a signal at both places, then both if stages are operating.

Parts placement and lead dress in these high-frequency if stages are critical. Substitution of components other than those specified by the manufacturer isn't advisable.

Troubles

What sort of troubles can we expect in the if stages? We will have all of those we discussed earlier in our study of the AM receiver, plus a few more.

The voltage on the control grid of the if tubes should be negative with respect to the cathode. This could be supplied through cathode bias or a grid-leak and grid-capacitor circuit. Sometimes, though, you will find a small plus voltage on the grid instead. This positive voltage can be caused by a number of defects. The first suspect is the tube. With your vtvm connected between grid and chassis, substitute a new tube and if the positive voltage disappears the old tube was gassy.

If the positive voltage on the grid remains, disconnect the primary (B-plus) lead of the if transformer. If the positive voltage on the control grid disappears when you do this, then you have voltage leakage through the insulation of the transformer. Replace the unit.

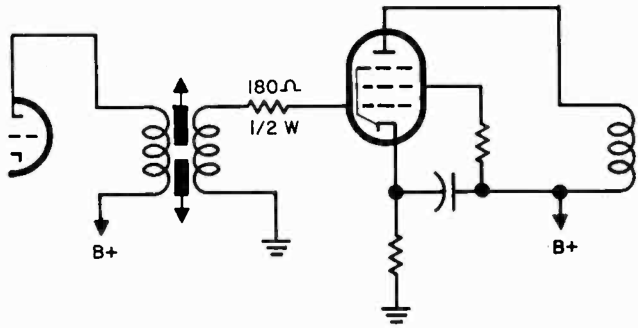


Fig. 719. *A small resistor inserted in the grid circuit of an if stage will help stop oscillation. If the if tubes are shielded, make sure the shield fits well and makes good contact with chassis, ground, or B-minus bus. Try not to disturb the wiring in high-frequency circuits. Lead dress is important.*

Although the positive voltage on the control grid may be very small, usually a fraction of 1 volt, its effects can be large. It will cause grid current. This grid current will change the response of the if transformer, making it tune more broadly. This, in turn, will make the receiver less selective, gain will go down, more noise will get through, all because of the broader frequency response of the transformer.

When you replace an if transformer, don't take for granted that because it is new, it is perfect. After you have installed the transformer, voltage check the grid.

Squealing

The if stages are amplifiers and, like most amplifiers, will oscillate if given a chance to do so. To find the trouble, connect one end of a

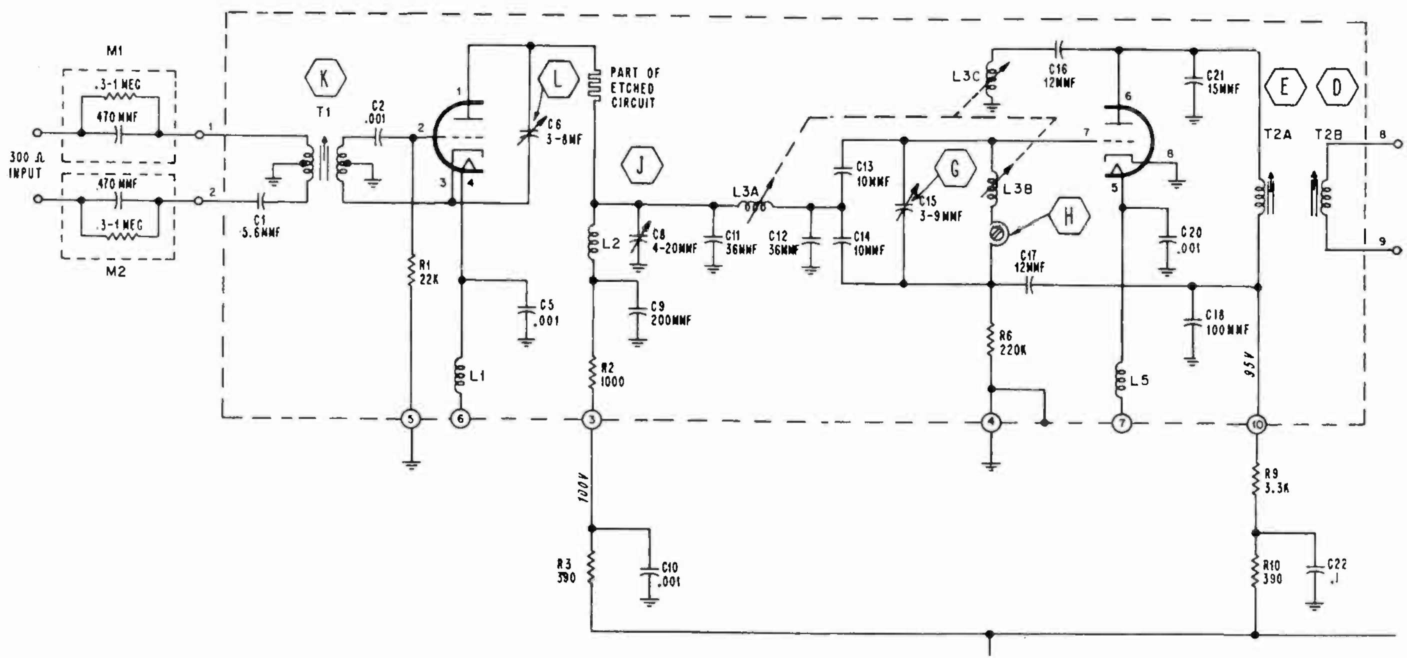


Fig. 720. *The tuner, consisting of an rf amplifier, an oscillator-mixer and the first if transformer, is completely enclosed in a shield. The rf amplifier is neutralized by variable capacitor C6.* (Admiral Corp.)

1-μf capacitor to the chassis. Now touch the other lead to each of the screen grids of the if tubes. If the oscillation stops a screen bypass capacitor may be open.

If this doesn't help, touch the lead of the capacitor to the terminal of the if transformer connected to the B-plus line. If this stops the oscillation, a decoupling filter capacitor may be open.

If the cathode resistor of the if tube has a bypass capacitor, remove it. This will add a small amount of negative feedback which may kill the oscillation. If this is helpful, but not enough, insert

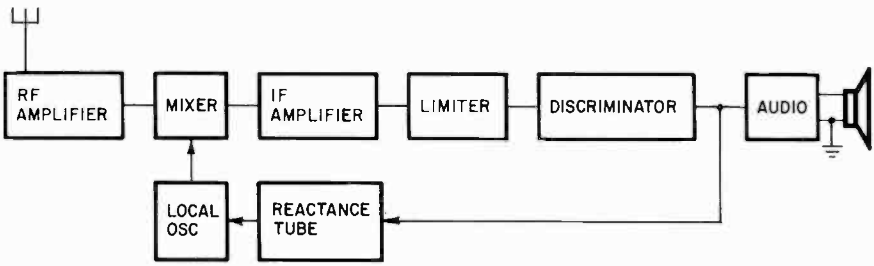


Fig. 721. *Block diagram of FM receiver using afc.*

100-ohm ½-watt resistors in series with the control grid of each if tube. To make this change, disconnect the lead of the if transformer going to the control grid of the if tube. Connect this lead to one terminal of the resistor. Now solder the other lead of the resistor to the control grid, just as shown in the schematic (Fig. 719).

Oscillation in the if will produce squealing and whistling and will make the audio very sibilant.

For all other if troubles, consult the chart given earlier.

The front end

Some FM sets have an rf amplifier ahead of the mixer. A typical circuit is shown in Fig. 720.

It isn't advisable to attempt repair of such units. Their adjustment and alignment calls for the use of some expensive equipment. If inspection shows that the front end is defective (burned components, broken printed-circuit board, etc.), it is best to disconnect the unit and replace it with a new one. If the tuner requires a new tube, try several until you find one that won't force you to try to realign the front end.

Automatic frequency control

Did you ever drive a car, take your eyes off the road for a mo-

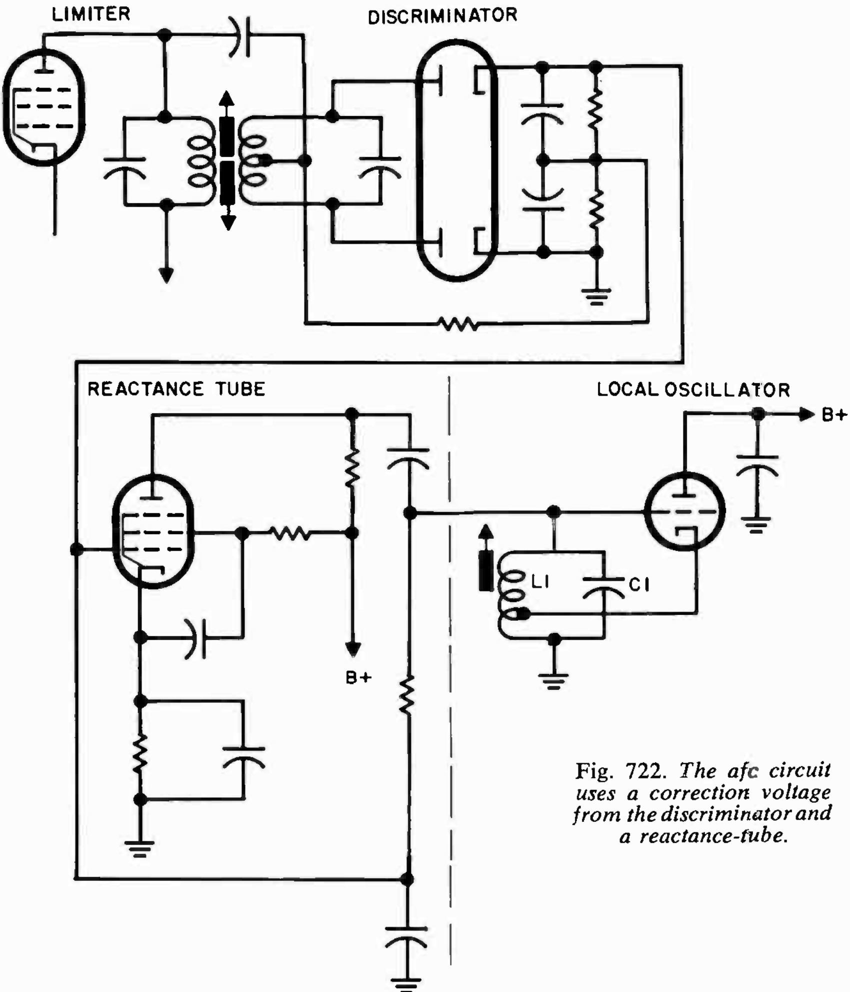


Fig. 722. *The afc circuit uses a correction voltage from the discriminator and a reactance-tube.*

ment and then suddenly note that you are almost off the highway. An FM receiver (or an FM tuner) can be like that. Its front end can drift in frequency. It won't do this right away. It will wait until you are nice and comfortable in some easy chair listening to a good program.

Drift in the front end will force you to get up and retune the set. This isn't a serious defect, but it is a nuisance and takes much of the enjoyment out of listening.

What is afc?

Afc is an abbreviation for automatic frequency control. Afc is a "kissin' cousin" of avc. Afc, though, is more complicated. As a start, suppose we examine the block diagram of an afc system as shown in Fig. 721. The block diagram is that of an FM receiver with just a single circuit added—a reactance tube connected between the local oscillator and the output of the discriminator.

In Fig. 722 we have the circuit. What has been changed? We still have our local oscillator and our discriminator. The mixer tube isn't shown but the local oscillator is coupled to it.

The reactance tube is shunted across the tank circuit (L1–C1) of the local oscillator. It acts just like a coil whose inductance depends on the amount of current passing through the reactance tube.

As long as the local oscillator is on its correct frequency (when we tune in a particular station) the dc voltage from the discriminator will be zero. A drift in either direction by the signal at the discriminator will produce either a positive or negative voltage which, when applied through the reactance tube, will change the oscillator frequency to bring the voltage back to zero.

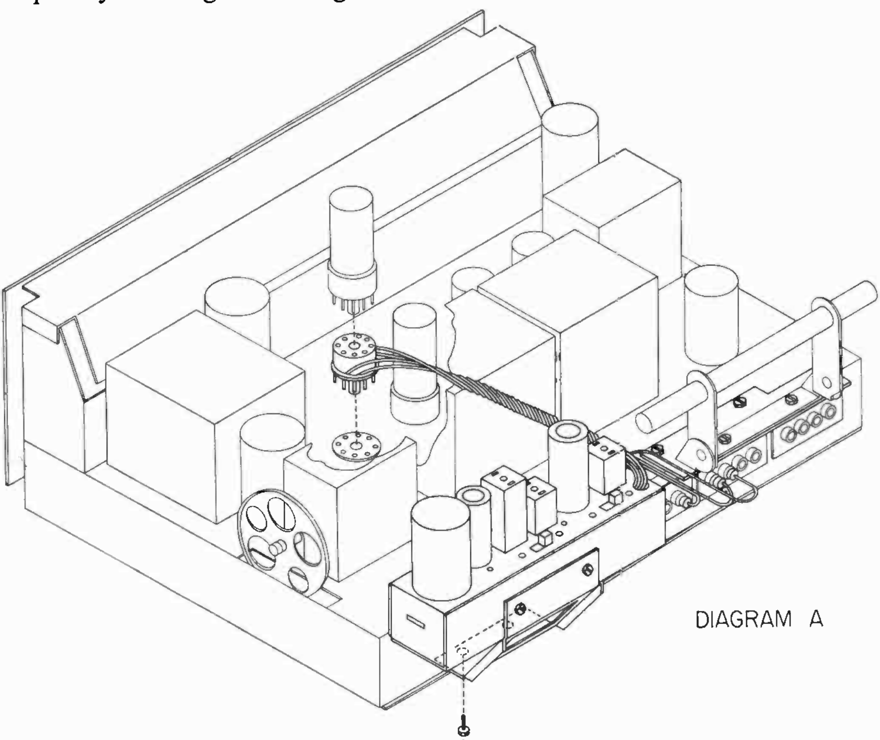


Fig. 723. *Small chassis attaches easily to the rear of FM tuner and obtains its power through adapter-plug. It is best to use multiplex stereo adapter only with receiver it was designed for.* (Harman-Kardon)

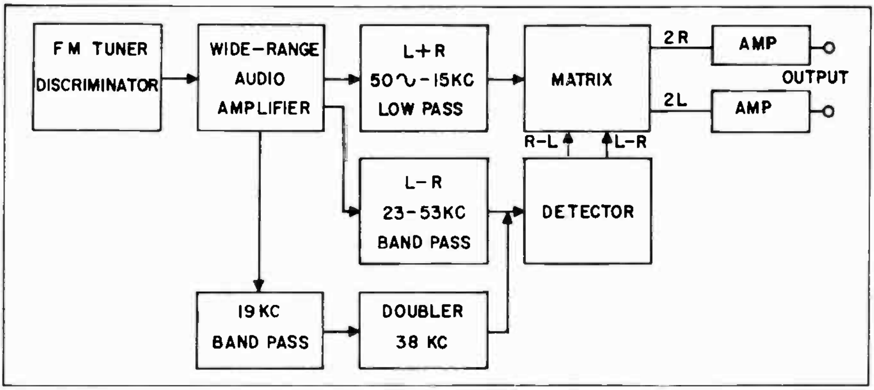


Fig. 724. *Block diagram is typical of one multiplex stereo system. Circuitry and alignment procedure can vary from one manufacturer to another. Always follow manufacturer's instructions.* (Philco Corp.)

Multiplex stereo

Not all FM detectors have a de-emphasis network (Page 2-92) and those that do may have an output jack between the network and the detector. For multiplex stereo the high frequencies usually removed by the de-emphasis network are needed. These frequencies for multiplex stereo operation go as high as 53 kc and if other multiplex services are used may extend to as high as 100 kc.

Multiplex stereo can be obtained from a two-tube sub-chassis (Fig. 723) or from a self-contained accessory complete with balance controls and power amplifiers. We have covered the audio amplifier portions in previous chapters. The only portion of the adapter that is new to us is the few tubes that do the channel separating.

The alignment of the tuned circuits in the adapter is extremely critical. These adjustments should not be changed unless the proper, accurate test equipment is available. A slight misadjustment here will be more noticeable than in the if amplifier or detector circuits. The first thing to be affected will be stereo channel separation. As misalignment increases distortion will also increase but do not suspect the multiplex stereo stage for all distortion. Eliminate all other possibilities first—remove the stereo adapter from the circuit if necessary. Use jumper wires to feed points 2R and 2L (Fig. 724) directly from the FM detector to bypass the stereo channel splitting circuits.

Should the multiplex tuned circuits prove to be defective and the proper equipment is not available it might be better to have a *factory authorized* service organization do the repair or at least the realignment if it is necessary to replace the tuned-circuit components.

QUESTIONS

1. What is the frequency range of the FM band?
2. Name three types of detectors used for FM. Which type requires a limiter?
3. What is a limiter? What is one of its characteristics?
4. How would you check a limiter circuit?
5. What is PIV? Name a component that would be marked in this way.
6. What is a surge resistor? Where is it used?
7. What problems can be caused by rectifiers in parallel?
8. How would you check for a shorted turn in a power transformer?
9. Describe two ways by which you could eliminate oscillation in an if stage.
10. What might be one cause of a positive voltage on the control grid of an if tube?
11. What are some of the effects produced by oscillation in an if stage?
12. Name three possible causes of distortion in an FM receiver. Assume that the output transformer and the speaker (or speakers) are in good working order.

CHAPTER 8

AM—FM tuners

DID YOU ever watch the way a trailer truck is assembled in a depot or garage? Huge trailers stand next to each other and while they are being loaded, the "business" end of the trailer is connected. It consists of a powerful motor with the cab sitting almost on top of it. When the cab and trailer are joined, you have a wonderful combination for hauling freight.

But what has this to do with us? Simply this—many ideas in radio receivers can be compared to something that seems as different as a trailer. Thus, some receivers are made up of tuners and amplifiers. The tuner is like the cab and the amplifier is like the trailer. When we join the tuner and the amplifier, we have a wonderful combination for listening pleasure.

What is a tuner? It is half a receiver. But half a receiver is like two young children dividing a bar of candy between them. Someone is going to get the bigger half. Generally speaking, then, a tuner consists of that part of the receiver up to and including the detector, but it may also have a stage of audio amplification.

Why should we have tuners?

At first thought, having a tuner might sound odd. Why bother with a tuner? Wouldn't it be better to have a complete receiver, ready to plug in and work? The answer here is the same as for our trailer and cab combination. What we're looking for is flexibility.

Suppose you (or your customer) own a record player, a tape recorder and possibly one or two microphones, all for home use. These are also what we would call "half" units. They just don't work by themselves. To get the benefit of the record player and microphones, we need the other half of the combination—an audio amplifier.

Now let's see what we have. In Fig. 801 we have our three units, all feeding into the audio amplifier but not at the same time, of course. Suppose we ask a question, though. Since we have an audio amplifier (usually a very good one and a fairly expensive one), why should we bother with a "whole" receiver? Why not buy just the half we need and just add it on.

The control unit

The next time you take a train ride, keep your eyes open for the control tower. If you're taking the train out of a large station, you'll

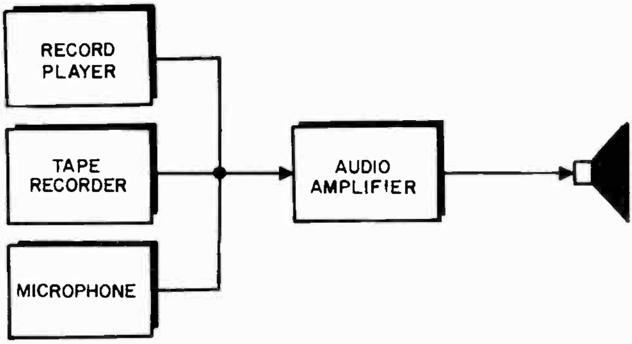


Fig. 801. *The same audio amplifier is used by a number of different signal sources.*

see the control tower almost as soon as the train leaves the yards. Without this tower, train traffic would be hopelessly mixed up.

Our control unit in Fig. 802 is a sort of electronic traffic control. Not only does it have one or more switches to select the input signal, but it may have a gain control, equalization circuits, bass and treble controls. Some have multiple outlets which are connected to the power line.

In Fig. 802 we have a number of units wired to an audio amplifier (through a control unit). Our tuner is one of these.

Tuner systems

A number of paragraphs ago we used the word flexibility. By this we mean that we can have our choice of a number of different combinations with tuners. You will see just what we mean by examining Fig. 803. Looking at the block diagram at the top (Fig. 803-A), we have an AM tuner feeding into a control unit. To make the drawing simple we have omitted all the other devices (phonograph, mi-

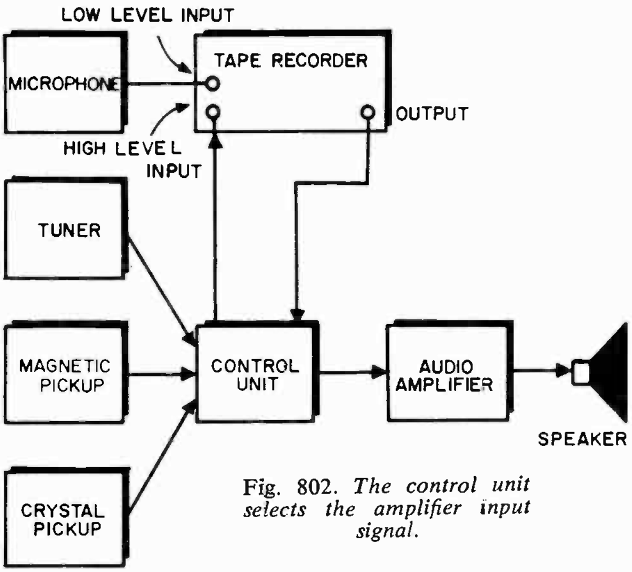


Fig. 802. *The control unit selects the amplifier input signal.*

crophones, etc.) that are also connected to the control unit. In some systems an AM tuner will be the only type that is used.

In the same way, we can have a setup using just an FM tuuner as in Fig. 803-B.

In Fig. 803-C we have two tuners connected to the control unit. One covers the AM band, the other the FM. Note that the tuners are separate items. They will each have their own chassis, power supply, cabinet and tuning dial. For a less expensive way of covering the two bands, the tuners are often combined into one as in Fig. 803-D.

Let's look at it

What does a tuner look like? Just like a receiver. Fig. 804 shows a combined AM–FM tuner. The control at the left is a switch. It turns the unit on, selects the band (either AM or FM). There is also one little refinement that is interesting. This is an afc control. The afc circuit is connected only when the knob is turned fully clockwise.

The knob shown at the right tunes both bands.

Tuner construction

In tuners, as in radio receivers, manufacturing methods range from the "get 'em out quick" type to those that are engineering delights. Many very fine AM–FM tuners are made and require much

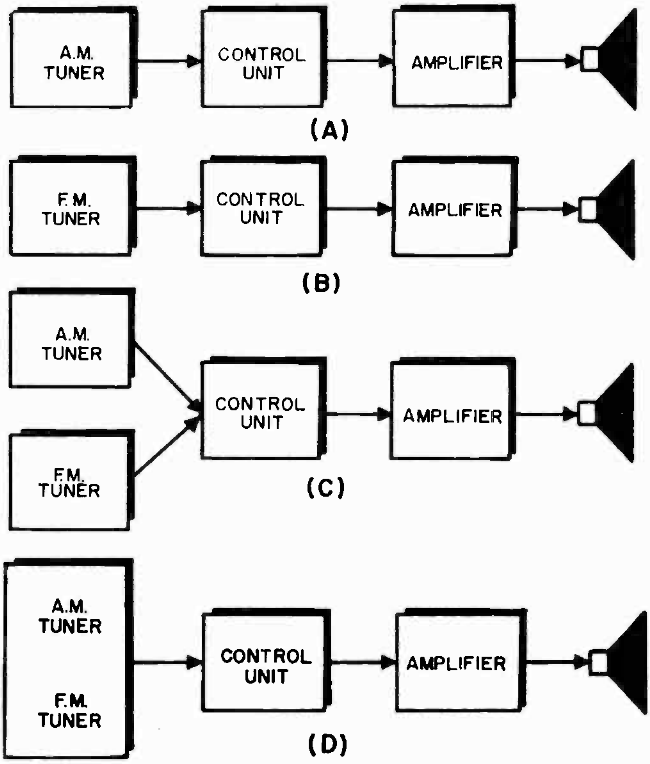


Fig. 803. *Tuners come in a number of possible arrangements.*

more careful servicing than the average radio receiver. The unit shown in Fig. 805 is completely shielded, has a total of three outputs (taken from the rear panel): AM–FM monophonic, stereo (FM and AM) and FM multiplex. The tuner has an afc circuit which keeps the receiver tuned to the center of the station channel. It also has an afc defeat position. This is a switch position for disconnecting the afc circuit.

Tuner circuits

Why should we study tuners when a tuner is only "half a receiver"? We've studied AM and FM receiver repair, so it is perfectly fair for you to ask whether we should bother with tuners.

It is true that the circuits in tuners are basically the same as those in receivers. That word "basically" is our clue. What we are going to look for are circuit refinements. There are also some circuits that appear in FM receivers that we have postponed until this time.

What are the differences?

We can start our work with a study of FM tuners. Your first question will probably be: "Are they all alike?" We can answer that

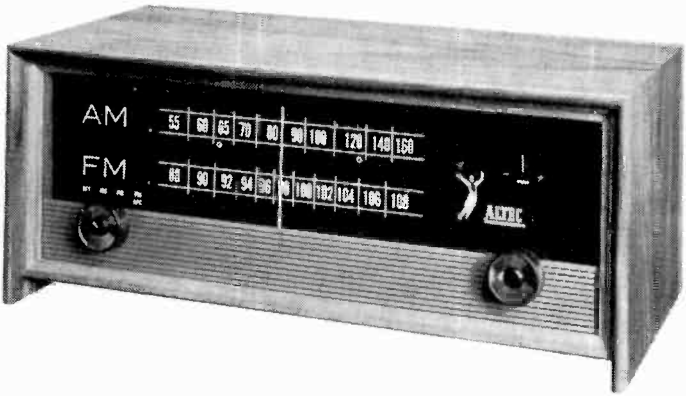


Fig. 804. *Combined AM-FM tuner with selection of afc.* (Altec)

with a question of our own. Why should they be? All radio receivers aren't the same and we have no reason for expecting that all tuners will be alike.

In Fig. 806 we have the block diagram of one type of tuner. The front end in this tuner uses a double-triode, one half of which is an rf amplifier while the other half is a mixer-oscillator. The unit has three if stages, a ratio detector and one stage of audio.

Another FM tuner diagram, shown in Fig. 807, uses a pentode

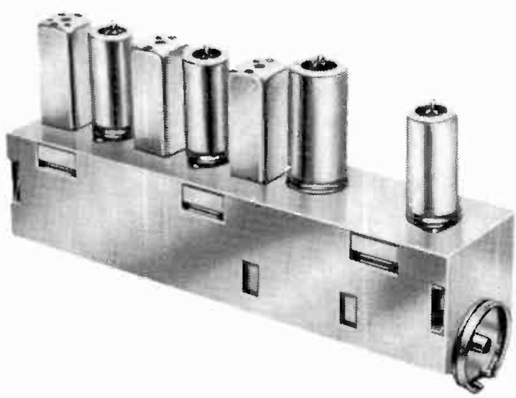


Fig. 805. *AM-FM tuner is completely shielded. It has three outputs.* (Harman-Kardon, Inc.)

rf amplifier, a double triode as a converter, two if stages, followed by a limiter and a discriminator–first audio amplifier. If you will compare the diagrams in Fig. 806 and Fig. 807 you will see that these two FM tuners are as different as they can be.

AM–FM tuners

What is the most complicated part of an AM–FM tuner? Probably the switching arrangement. The switching circuit, though, depends on just how the tuner was designed. Some AM–FM tuners use the same tubes for many circuits. As an example, the same tubes

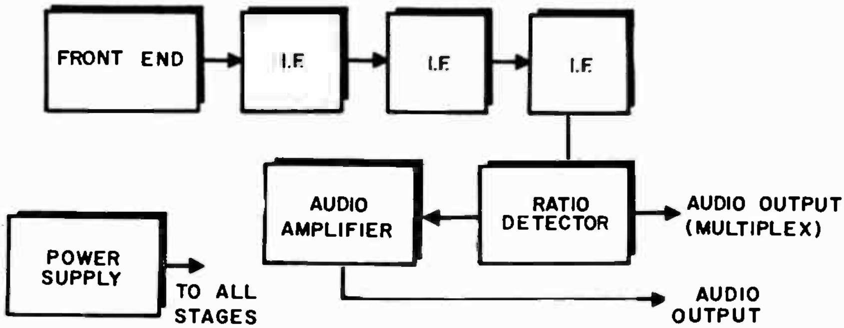


Fig. 806. *FM tuner with three if stages, ratio detector and two audio outputs.*

could be used for the if strip. In a case of this kind a switch may be needed to shift from AM to FM intermediate-frequency transformers.

In some AM–FM tuners, the two portions (AM and FM) are more independent of each other. In Fig. 808 we have the block diagram of such a tuner. Only two circuits are used in common by both tuners. These are the power supply and the detector tube.

In Fig. 809 we have the block diagram of an AM–FM tuner that uses the same tubes for both portions of the tuner. The rf amplifier is intended for FM only. When the tuner is switched to AM reception, the rf amplifier is not used, the AM signal being led directly into the converter.

In a tuner of this type the entire operation depends on switches. Because so many circuits are involved, the switching gets to be quite complicated.

Converters

There is another type of unit, somewhat smaller in size, that you may mistake for a tuner. Known as the converter, it is simply a frequency changer. With its help a broadcast receiver can be made to operate on higher-frequency bands. Converters will be described in the last chapter.

FM auto tuners

Servicing an AM receiver is simple in at least one sense. The entire unit is self-contained and you don't have to worry about inter-

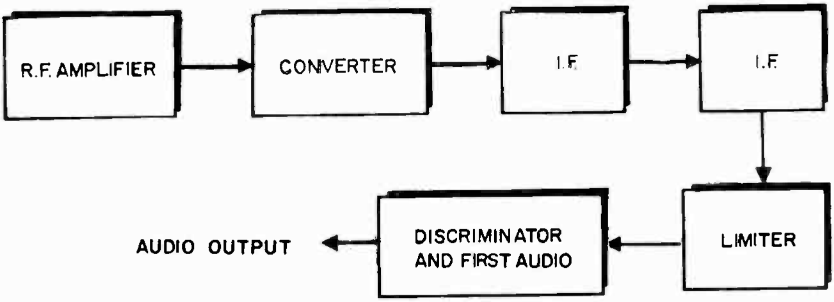


Fig. 807. *This FM tuner has two if stages and a limiter, followed by a discriminator-type detector.*

connections with any other unit. The tuner, however, whether it is AM or FM, is part of a system.

The man who likes to listen to FM in his home sometimes likes to listen to FM in his car. But now he has a choice. He can have two radios, one for AM and the other for FM, or he can have an FM

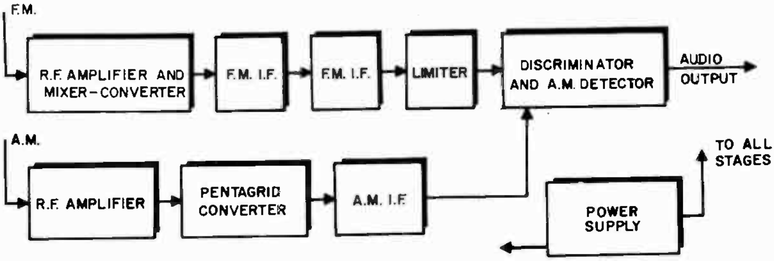


Fig. 808. *In some tuners, the FM and AM sections are separate units.*

tuner. As in any home system, the output of the FM tuner feeds into a power amplifier which drives a speaker.

In the home system a well designed audio amplifier serves as the receiving depot for a variety of input signals—AM, FM, phono, etc. The auto doesn't have this advantage. There is no separate audio

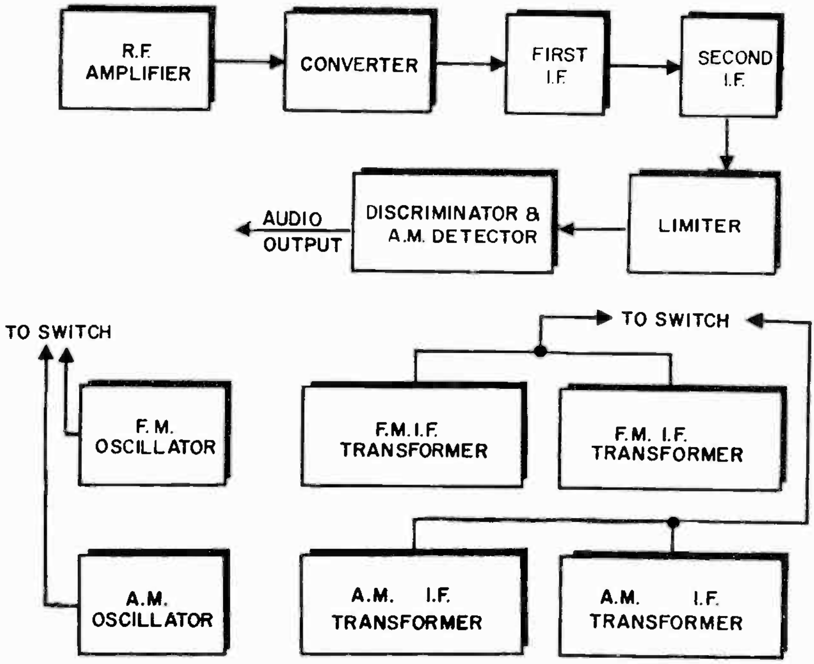


Fig. 809. *In some AM-FM tuners more circuits are used in common but the switching is more complicated.*

amplifier and so the output of the FM tuner is fed into the audio amplifier of the car's AM receiver. However, since the car does come equipped with an AM receiver, the tuner is designed for FM reception and its switching arrangement is quite simple.

We begin at the beginning

In earlier chapters we started our servicing by working our way back from the speaker to the front end of the receiver. This time we are going to begin with the front end.

The rf amplifier

What is so different about the rf amplifier for the tuner? Not too much except that in some sets you will find two rf amplifiers, one for the FM and the other for the AM band. In Fig. 810 we have a circuit for the rf stages in such a tuner.

Before we load ourselves with troubles, let's examine the circuit and see what we can spot at once. The amplifier for the FM section is a triode, so we certainly aren't going to get too much gain. We

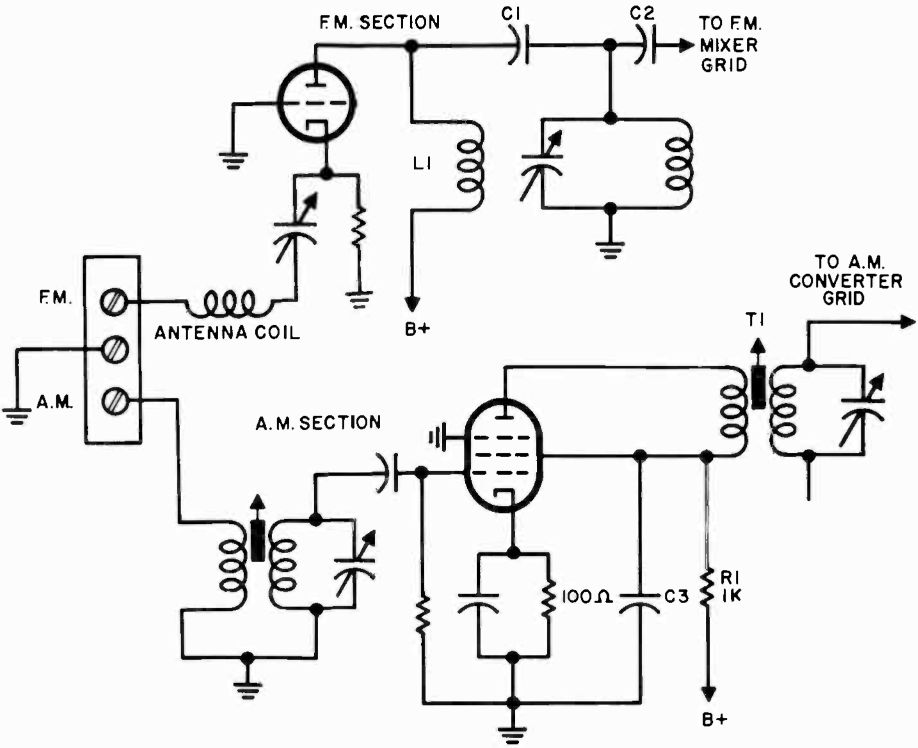


Fig. 810. *Separate rf amplifier stages are used in some tuners. The tube for the FM section is a grounded-grid amplifier.*

can also see that the tube is a grounded grid amplifier. The input is low-impedance to match the antenna circuit while the output is high-impedance, suitable for connecting into a tuned load. The big advantage of using a triode this way is that the input and output circuits are shielded from each other by the grounded control grid. Another advantage in using a triode is that a three-element tube produces less noise than another type, such as a pentode. In the AM section, though, a pentode is used.

Trouble, trouble

What is our first question in servicing a tuner? What's wrong? This question has just two words but it does cover quite a bit of ground. In Fig. 810 our first step would be to find out which half of the tuner is causing trouble. Is it the AM section or the FM? Set the selector switch, first on one band (such as the FM) and then on the other. If the AM band works but the FM does not, then we have immediately eliminated half the unit for servicing. At the same time we know that we don't have to worry about the power supply, since it furnishes voltage for both AM and FM sections.

Let's set up a table of troubles so that we can have it handy when we work on tuners.

Troubles in the RF Amplifier.	And What to Do About Them.
No sound when set is switched to AM or FM.	It is unlikely that both amplifier tubes are defective but it can happen. Check them.
	FM and AM terminals on antenna terminal board are shorted to ground.
	Check B-plus lines. The plate and screen circuits connect into a common line that goes to the power supply. Make sure this line reaches the power supply and that it has voltage on it.
AM has sound; no FM sound.	Click test FM tube.
	Try a new tube.
	Tube is a miniature and may not be properly seated in socket. Pins may be bent, not making good contact. Socket may be defective or dirty.
	Check plate voltage. If no plate voltage, resistance check plate coil L1 (in Fig. 810) for continuity.
	Check bias voltage. Cathode should be slightly positive (fraction of a volt) with respect to ground. If cathode is at zero potential, tube isn't drawing current and either the bypass capacitor is shorted, the plate coil is open, or tube emission is gone.
FM has sound; no AM sound.	Try a new tube. Click-test old tube.
	Check plate and screen voltages. If no plate voltage, check the primary of coupling transformer T1 or decoupling resistor R1. Tube will not work if cathode resistor is open.
	Check bias. Grid should be a fraction of a volt negative with respect to cathode. If no bias, tube isn't drawing current.

Sound is weak; may or may not be distorted (either AM or FM).	Defective tube.
	Wrong plate or screen voltages.
	Bias is incorrect. Cathode resistor has changed value or cathode bypass capacitor has shorted.
Pinging sound in speaker.	Tube may be microphonic. Tap gently. Pinging sound in speaker indicates microphonic tube.

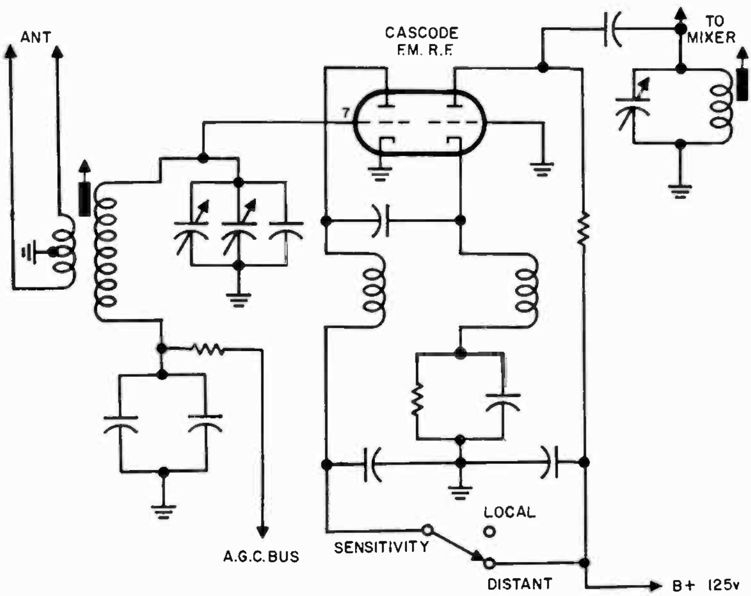


Fig. 811. *The local-distant switch controls the gain of the rf amplifier.*

Scratching sound when set is tuned.	Caused by noisy tuning capacitor, generally in AM section; rotor plates rub against stator. Trouble may be in either section of variable capacitor. To check, disconnect leads to capacitor and shunt ohmmeter across capacitor. Turn dial from open to full mesh. Meter should show infinite resistance. If meter needle moves back and forth when dial is turned, capacitor plates are rubbing. Adjust plates of capacitor until short disappears.
	Trouble may also be due to dry ball bearings or rubbing action of rotor shaft. Lubricate with anti-noise lubricant, commercially available.

The cascode tuner

The triode in Fig. 810 for the FM section is a grounded-grid amplifier. Sometimes the tube is in series with a triode amplifier, the combination, as shown in Fig. 811, being known as a cascode tuner.

For weak signals the cascode tuner is fine but with a strong signal we may run into a nonlinear part of the tube's characteristic. One way of cutting down the gain is to operate the tube with a greater amount of bias voltage. Another method is to eliminate the first half of the double triode used as an amplifier.

In Fig. 811 the sensitivity is controlled by a local–distant switch. When the switch is in the distant position, the plate of the first triode section gets its usual ration of B-plus voltage. For strong signals, B-plus is removed from this tube. There is enough capacitance between the tube elements of the first triode section to transfer the signal to the cathode input of the grounded-grid amplifier.

If the tuner works well on local, (nearby) stations but is weak on more distant ones, check the voltage on the plate of the first triode. Absence of voltage here (while you work the sensitivity switch back and forth) means a defective switch.

Other front ends

Whether or not a tuner will have separate front ends will depend on its design. With two front ends, one for AM and the other for FM, switching is reduced to a minimum and might be nothing more than a single-pole double-throw switch. Where there is only one front end that must do double duty for both the AM and FM bands, switching circuits become complicated.

Some tuners are constructed in combination with record changers or record players. In these systems the switching system is used to turn the tuner off but permits line voltage to be sent along to the changer motor and B-plus to the audio amplifier.

Servicing the system

What are we trying to do when we service a tuner? Wouldn't you say that we are trying to fix two receivers at the same time—AM and FM? But is it likely that both receivers will be out of order at the same time? We cannot give a definite answer to that one since it all depends on the type of system used.

What is our first step in servicing, then? The big question is whether the trouble exists in the tuner at all? Does the audio section work? That's easy enough to determine. Follow the servicing procedures learned earlier. Turn the unit on. Switch to phono. Then touch the tip of the stylus in the phonograph pickup to see if sound comes through. Or, put a disc on the turntable. If there is no sound, your trouble isn't the tuner. Look for trouble in the amplifier, the power supply or the power line.

The power supply

Tuners come equipped with their own power supplies. The fact that the audio section of the system is working proves nothing

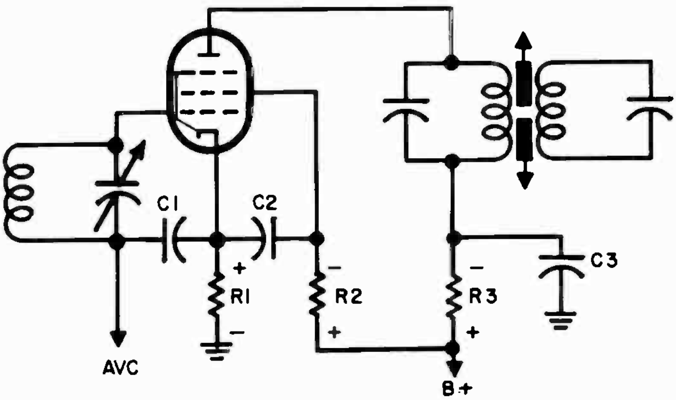


Fig. 812. *If a circuit uses resistors, voltage analysis can be used to supply considerable information about all the components.*

concerning the supply for the tuner. If both AM and FM bands are dead, the B-plus line is a good place to start checking since it is common to both tuners. The B-plus line isn't always part of the switching arrangement, so you can trace right on out to all tubes. In some sets that use separate rf amplifiers, though, B-plus voltage is often switched off the amplifier not in use.

Antennas

On the back of the tuner you will find a terminal board with provision for external antenna connections. In some tuners you will find connecting screws for both AM and FM antennas; in others there will be provision for FM only.

Whether external antennas should be used depends on location and signal strength. Generally, no outdoor antenna is needed for

AM. For FM a good outdoor antenna is helpful in nearly all areas. If, in the tuner you are servicing, the AM section works well, while FM is poor, try checking the antenna arrangement.

Servicing the if by voltage analysis

Ever turn on a faucet and have water come out, drop by drop, and then, after a second or two, nothing at all? You don't have to be a plumber to know you have trouble.

An amplifier tube is like a valve or faucet. The tube isn't supposed to deliver current—just control it. It can't do this unless current passes through it.

But how can we tell? In the case of the faucet we have no problem. We can see water, but a current of electricity is invisible.

If we walk into a kitchen and see a faucet we have a pretty good suspicion that water is somewhere around. And, in a radio receiver, if we can find the voltage, we can usually locate the current.

Every time current flows through a resistor we get a voltage across that resistor. Armed with this bit of information, we can learn if a current is going through a tube.

Whether we can measure voltage drops depends on whether the circuit has resistors for us to work on. We can measure the voltage at the plate of the tube, but the dc resistance of the primary winding of the if transformer could be so small that the voltage at the plate and at the B-plus bus would be practically identical.

In the case of Fig. 812 opportunity doesn't need to raise its hand to knock even once. Here we have three resistors, each ideal for the sort of test we have in mind.

We can approach voltage analysis in several ways. First set your vtvm to read low dc volts. Put the probe at the cathode and the common lead at ground. You will then be reading the voltage across R1.

There are four basic possibilities:

(a) the voltage across R1 is correct

(b) the voltage across R1 is too high

(c) the voltage across R1 is too low

(d) there is no voltage across R1

Analyze these, in turn. Suppose the voltage across R1 is correct? What does that tell us? We know immediately that the bias is right, that screen and plate voltages must be right, that the tube is passing current and that C1 and C2 aren't shorted. That's quite a few answers to get for just one measurement.

But we're not interested in circuits that work correctly. Suppose, then, that the voltage across R1 is too high. What does that tell us? This informs us at once that the tube is drawing too much current. But why?

This could happen if the tube were gassy. If the tube is made of glass, examine it around the inside near the base. Is there a small whitish deposit? If so, get a new tube. The old one has a leak in it.

Check the control grid. It should have a negative voltage on it supplied by avc action. Tune to a strong station. Generally, though, even the absence of avc voltage will not affect tube current too strongly. But there is a possibility of B-plus leaking over to the control grid through corrosion in the if transformer or through some high-resistance short to B-plus.

Now consider the case when the voltage across R1 is too low. One possibility would be weak emission in the tube itself. It takes current to produce a voltage drop and the cathode of the tube just may not be emitting.

Another possibility might be that the plate isn't attracting enough electrons. It would do this if, for some reason, plate voltage was lowered. What could cause this? The tube might have low screen voltage due to an increased value of R2 or no screen voltage if R2 were open. R3 might also have gone up in value, reducing plate voltage.

Suppose C3 became very leaky. It would force more current through R3, producing a larger voltage drop across it. But the more voltage we drop across R3, the less we have for the plate. And the less we have for the plate, the smaller the amount of current through the tube, and the smaller the voltage across R1.

Finally, what if we have no voltage across R1? The tube isn't drawing current. This could be caused by a completely dead tube, or by a heater-cathode short (or a shorted bypass capacitor as in Fig. 813).

Other voltage checks

Now do you see what a tremendous amount of information we can get out of a simple voltage check? But there are others. We can tell if the screen is working by measuring the voltage drop across R2. Not only that, we can use this test to tell us if C2 is leaky. Connect the negative lead of your vtvm to the screen grid.

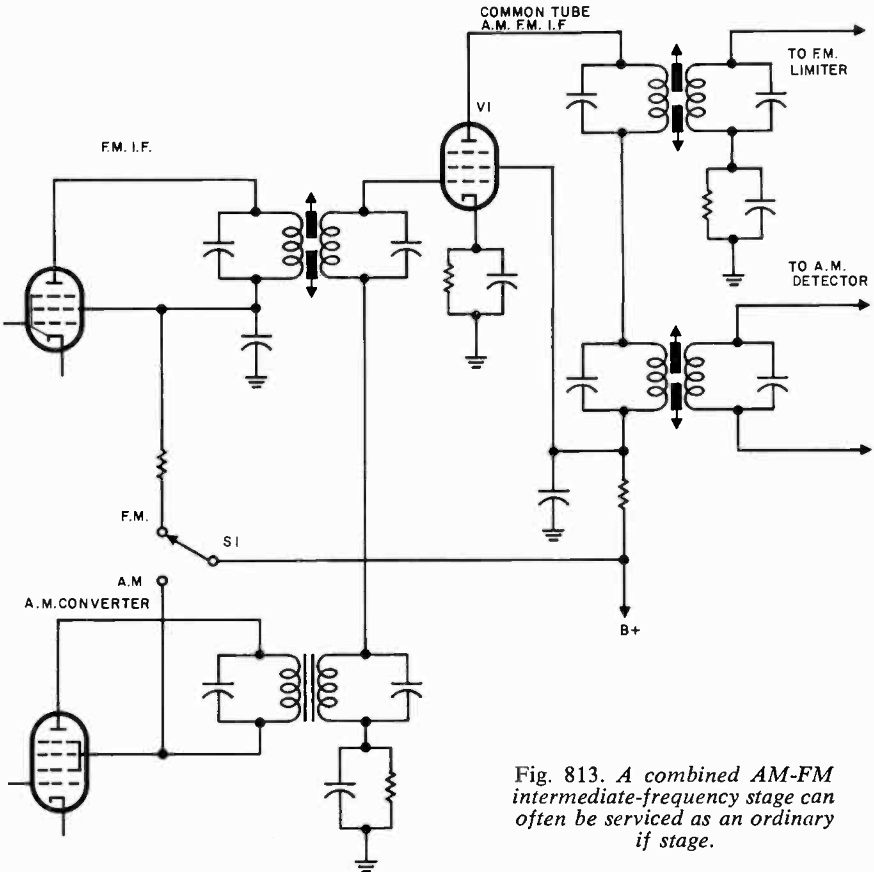


Fig. 813. *A combined AM-FM intermediate-frequency stage can often be serviced as an ordinary if stage.*

Connect the plus lead to the B-plus line. Disconnect one end of C2 (the end connected to the cathode). The voltage reading on the meter should not change. If, for example, the voltage reading across R2 should decrease, replace C2. It is too leaky.

You can also make a voltage check across R3. Connect the vtvm test leads across it, following the polarity indicated in Fig. 812. Now disconnect the ground end of C3. If, with C3 disconnected, the voltage across R3 goes down, replace C3.

While we have selected an if stage for voltage analysis, you can use the same tests on any amplifier stage that uses resistors.

More notes on the if section

Servicing the if section depends entirely on the design of the tuner. If there are separate if stages—an if strip for the AM section and another if strip for the FM, then you can handle the tuner just as though you were working on two separate receivers. It is very unlikely that both sections would become defective at the same time.

Many tuners, though, have a common if as shown in Fig. 813. In this circuit the AM converter feeds into a circuit designed to amplify both the AM and the FM intermediate-frequency signals.

To keep the common if tube from getting hopelessly confused, we have a switch in the B-plus line. When the switch is turned to AM, the first FM intermediate-frequency stage gets no B-plus. In this way, only one if signal at a time is fed into the common tube.

The if transformer in the output of V1 consists of the primary

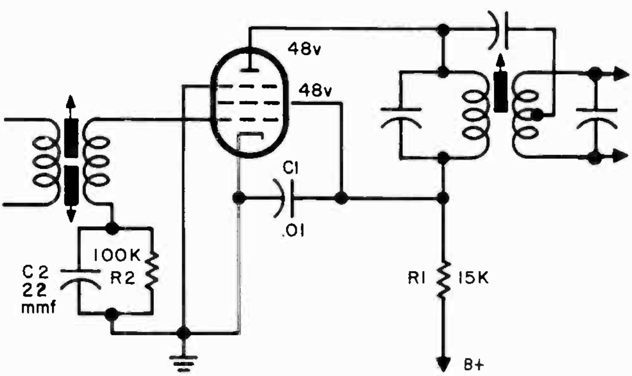


Fig. 814. *The limiter operates with low plate and screen voltages.*

windings connected in series. The if of the FM section is 10.7 megacycles and, as a result, the if transformer has very few turns.

Now consider the two if frequencies we have. One is 455 kc and the other is 10.7 mc. Quite a difference. For 10.7 mc, the AM winding of the if transformer is simply a reactance in series with the transformer. For 455 kc, the FM winding is just a small reactance.

Suppose, though, that we had the switch set to receive FM. Couldn't some of this get through to the AM detector? Possibly. But following each detector we would have another switch, ganged to S1 in Fig. 813. This second switch would make sure that only one detector's output is used at a time.

Troubles in the if

How do we check a circuit such as the one shown in Fig. 813?

In this case we can make the switch, S1, help us determine which section, AM or FM, is out of order.

To analyze troubles in V1, treat it as though it were an ordinary if stage. You can inject a signal for AM output, or you can run a voltage analysis.

Switch S1 is in the B-plus line. If you cannot get voltage on the AM converter tube (no matter what position the switch is in) run a resistance check (test for open and short) on the switch.

Quite often the only trouble is oxidization of the switch contacts. Treating it with a lubricant cleaner will put it into operation again. Be suspicious of the switch if the set is intermittent or if you can make the set play by jiggling the switch or exerting some pressure on it.

The limiter

A better name for the limiter is AM clipper. The circuit, as shown in Fig. 814, works with very low values of plate and screen voltages and has its cathode tied to ground. As a result, the tube saturates easily.

Not all sets have limiters. You will usually find them with receivers using a discriminator type detector, although they are sometimes also used with a ratio detector. Most sets with limiters have just one, but you may come across a tuner having two. The idea here is that one limiter will remove AM variations from the top of the waveform, while the other will take care of the bottom of the wave.

Troubles in the Limiter Circuit.	And What To Do About Them.
Receiver noisy.	Try a new limiter tube. We depend on cathode emission to get a saturated current. Check screen bypass capacitor C1 (in Fig. 814). Screen and plate dropping resistor R1 may have decreased in value, putting too high a voltage on plate and screen. Limiter transformer detuned.
Very weak signal.	Defective limiter tube. Open dropping resistor R1. (Some signal may get through even though tube will have no B-plus.) Shorted or very leaky C1. Open grid-leak resistor R2.

Distortion.	Defective limiter tube.
	Grid-leak network (C2 and R2) changed in value.
	Limiter may be oscillating.
	New tube may sometimes cause distortion. Limiter transformer may need realignment when new tube is used.

Whenever we use a circuit, such as a limiter, we pay a price. In the case of avc, the price we pay is in reduced gain, since the stronger the signal, the more the gain of the controlled tubes is cut down.

We have a similar idea in a limiter circuit. Signals of a certain strength will produce saturation (maximum current flow) through the limiter tube. Having a stronger signal will do us no good, since

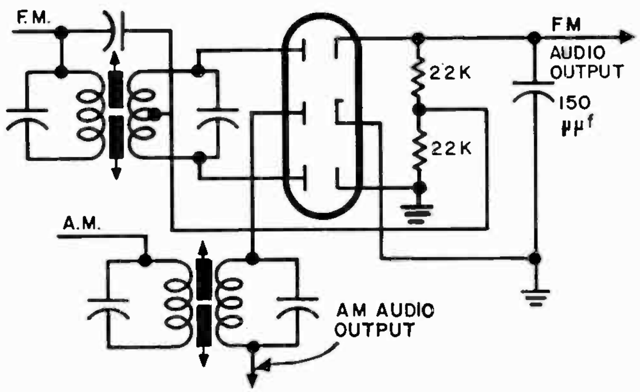


Fig. 815. *This tube is a combined AM and FM detector. The FM section is a discriminator. The AM is the usual diode type detector.*

the output will be constant for all signals over and above those producing maximum limiter current. We can solve this problem by raising the voltages on the plate and the screen of the limiter tube, but then we would need a stronger signal input to reach saturation again.

In the same way, by having lower plate and screen voltages, we can get limiting action for weak signals, but at the sacrifice of signal strength for stronger signals.

Quick check

If you want to know (quickly) if the limiter is working, set your vtvm to the *minus* 10-volt dc scale. Connect the probe of the instrument to the top part of grid-leak resistor R2 and the common lead to ground. Tuned between stations, the voltage reading should be zero. Now set the dial to a strong station. You should get a reading of 3 to 40 volts, depending on the signal strength and the gain of the stages ahead of the limiter. If you get no voltage reading at any time, either the limiter isn't working or some stage ahead of the limiter is defective.

The double detector

By the time we reach the detector, all signals can be funneled into one tube. This tube, as shown in Fig. 815, is a combined discriminator (for FM detection) and single diode (for AM detection). The unusual feature of Fig. 815 isn't the circuit–it's the tube.

Double-detector troubles

Since this is a meeting point for both AM and FM signals, both bands may be affected at the same time. If signals are weak or missing on both AM and FM bands, substitute a new tube.

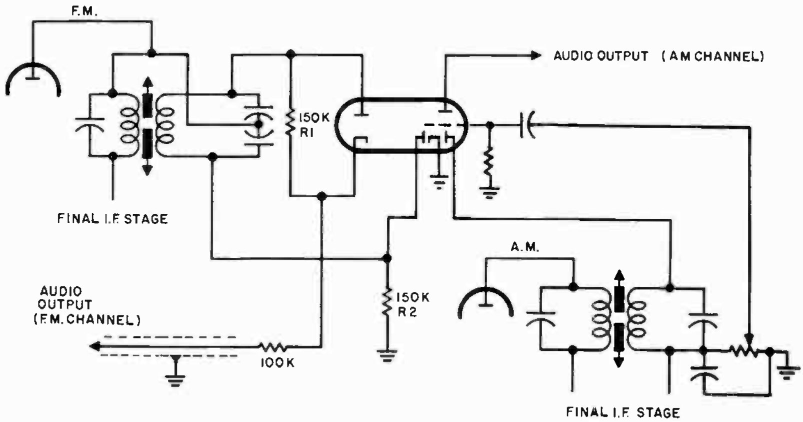


Fig. 816. *This circuit is similar to that of Fig. 815. The FM detector is a discriminator. The AM section uses a diode detector but this is followed by a stage of audio amplification. The audio output of the FM discriminator does not have this feature.*

You can run into odd troubles at this point. We can't expect equal signal strength out of both bands. In a fringe FM area, a low emission in the detector tube could result in very weak audio when the set is switched for FM. However, AM signal strength could be strong enough so that weakness in the detector tube might not be recognized. You can't expect both channels to drop strength in equal amounts.

If you get distortion when tuned to FM but not AM, check the 22,000-ohm diode load resistors. They should be equal in value for FM. The two resistors are not used for AM.

Double detector and audio

In Fig. 816 we see how the idea of using a double detector is carried just one more step. Basically, the idea is exactly the same as that shown in Fig. 815 but now the tube is also used as the first audio amplifier for the AM section.

Because of the tube arrangement you may not spot the FM diode

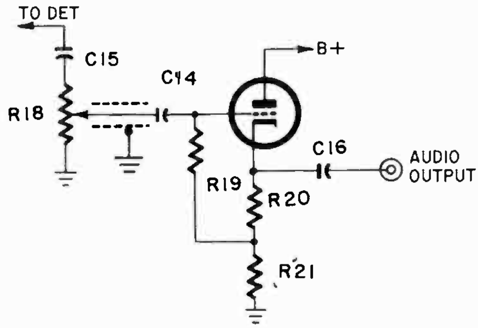


Fig. 817. *In some tuners, a cathode follower is the audio output stage. The signal at the output of the follower is less than at the input.*

load immediately. Look for a pair of equal value resistors. In Fig. 816 these are R1 and R2. Note in this case they are 150,000 ohms, a much higher value than the 22,000 in Fig. 815. They must still be fairly equal in value. Check with an ohmmeter. If either resistor is off value by more than 10%, you have an unbalanced condition that will upset the sound.

Other detectors

Not all tuners use a double detector tube. In some, the FM detector will be either a ratio detector or a discriminator. The detector for AM will often be a semiconductor. With this arrangement you can work on the circuits separately, following the procedures given in an earlier chapter for servicing such detectors.

Having separate detectors will simplify repairs since the detectors are independent of each other. If FM sound is weak, distorted or missing, the ratio detector could be responsible, but you would not need to concern yourself with the AM detector. It's like having two horses pulling a wagon. It wouldn't take you very long to find out which horse needed to be rushed to the vet.

Output circuits

In some tuners the output of the detector is the end of the line. This isn't always the case, since you will sometimes find a single stage of audio amplification. This could be an ordinary resistance-coupled triode amplifier or a triode working as a cathode follower. In some tuners, a dual triode is used—one half for FM sound, the other half for AM.

The cathode follower

Ever watch a baby in a high chair at feeding time? A lot of food is pushed into a very reluctant mouth and almost as much comes spilling out. Some amplifiers are like that, and the cathode follower is one of them. No matter how much signal we stuff in, we always get out less.

In the cathode follower the signal input is between control grid and cathode while the output is taken off the cathode resistor. The use of the cathode follower is a loss of gain but it's a fine way of connecting a high-impedance circuit to a low-impedance load. We could have used a transformer for this purpose but it would take a well designed and expensive unit. The cathode follower costs less and does the job very nicely.

One circuit is shown in Fig. 817. In this case our servicing has been made a bit easier since it appears in a tuner for FM only.

Cathode-follower troubles

The cathode follower of Fig. 817 is an audio tube. This means that we can test it just as we would any audio amplifier circuit, keeping in mind that we won't have any audio appearing at the plate of the tube. The plate is connected directly to the B-plus line and since this is always bypassed with high value capacitors, we have the plate at zero or ground signal potential.

You can check the circuit by click-testing it or by using any of the methods described earlier. Or, you can connect a scope across the input and the output, in turn. The cathode resistor, now acting as the load resistor, isn't bypassed any more than we would bypass a plate load.

No signal out of the cathode follower could be caused by a defective tube, an open in either of the coupling capacitors C14, C15 or C16, an open R19 (the grid-return resistor), or lack of B-plus on the plate.

Note the two resistors used in the cathode circuit, R20 and R21. Resistor R20 supplies self bias for the tube but R20 and R21 in series represent the output load. To determine the correct amount of bias, measure the voltage drop across R20 alone.

Not all cathode followers use two series resistors in this manner. In some followers just one resistor is used, this single resistor acting to supply self-bias and at the same time working as the load.

Volume control

There's one thing we can say about tuners and that is you won't ever get bored with them. It's doubtful if any two tuners are exactly identical. The chances for being "different" are very good and it

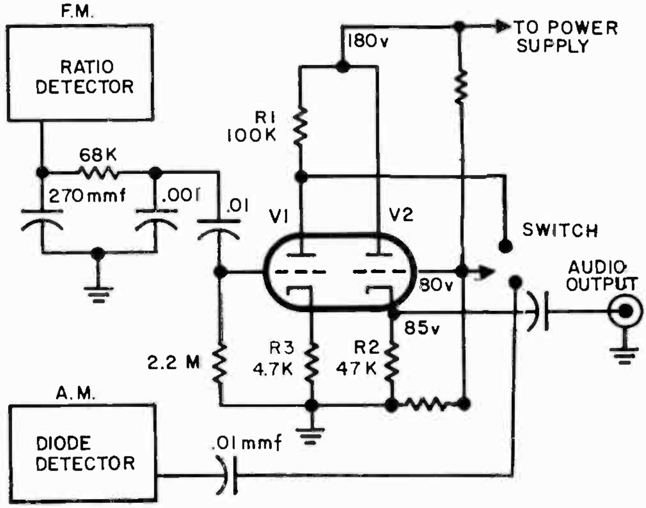


Fig. 818. *A double-triode is sometimes used for the audio output section of a tuner.*

does seem as though each manufacturer is trying his best to make them that way. You will find volume controls in some tuners, but don't reach for the knob instinctively. It may not be there. Some tuners have volume controls, others do not.

The circuit in Fig. 817 does have such a control. Note that the wire to the control from the cathode follower grid is shielded as shown by the dashed line, marked as being connected to ground.

The shielded cable used for this purpose can be very tricky. It is separated from the wire by an insulating plastic material which melts very nicely in the presence of heat, such as that supplied by a soldering iron. Since the shield is grounded, it shorts the signal to ground if, through some accident, the shield touches the center wire. This trouble usually happens at either end of the shielded wire, where it attaches to coupling capacitor C14 or to volume control R18. An ohmmeter check will tell you whether the wire has shorted to its braided shield.

If you need to replace the shielded wire, don't be tempted into using ordinary wire. The purpose of the shield is to keep hum and noise pickup out of the audio system. And when you do put in shielded wire, make sure that it is grounded. Ground does not mean laying the shield in against the chassis. Ground means a good ground. Wrap one turn of bare No. 22 tinned copper wire around one end of the shield. Solder as though you were working with a transistor—neatly and as quickly as possible. Solder the other end of the wire to a nearby ground point on the chassis.

Don't take for granted that your workmanship is perfect. Resistance check the wire to make sure you haven't grounded the "hot" lead. And don't make the wire any longer than you need.

Double-triode output

Fig. 818 shows another way of getting the audio out, in this case from an FM–AM tuner. The FM section has its own demodulator, a ratio detector circuit, while the AM side uses a diode (crystal) detector.

If you've ever eaten in a boarding house, you probably have noticed that the best seats at the table are those nearest the kitchen. This is the unloading point. Fig. 818 reminds us of that situation.

The FM side of the tuner is favored in this case. Its signal gets fed into V1, the first half of the double triode. V1 amplifies the signal and then sends it along to V2.

V2 has no favorites. It works as the cathode follower for both the FM and AM detectors, but the FM signal does get the advantage of being amplified by V1.

Servicing the amplifier-cathode follower

The circuit shown in Fig. 818 is only a partial schematic so we mustn't let it push us into any false conclusions. Our tube, V1-V2,

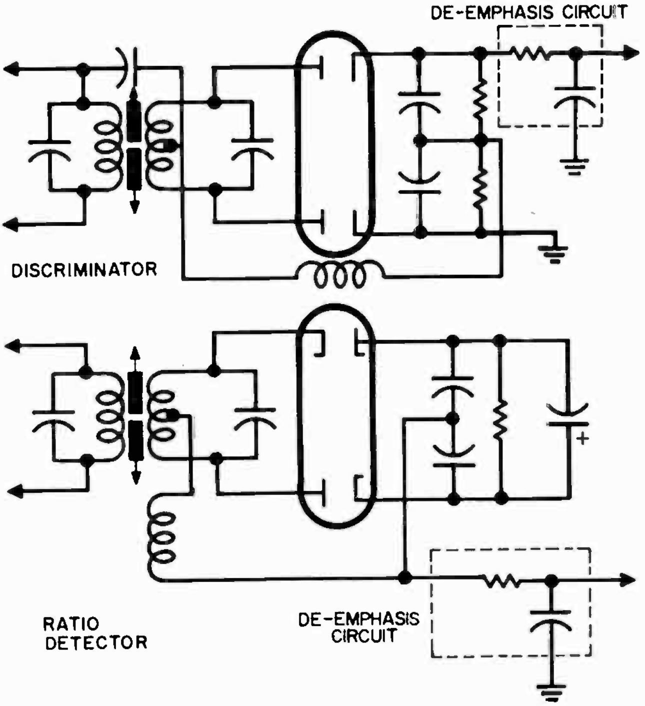


Fig. 819. *The de-emphasis circuit can cause frequency distortion if its values change.*

receives the audio from either the ratio detector or the AM detector, but not from both at the same time.

As a quick check on V1–V2, touch the grid of V1 with a screwdriver. A loud hum or squawk will tell you that the tube is working. If the sound is weak, try a new tube.

V1 is directly coupled into V2. This means that the plate voltage on V1 will also appear on the control grid of V2. However, the cathode of V2 has 85 volts on it, so the bias of V2 is 5 volts. If you get distortion, check the bias voltage. If the bias isn't what it should be, resistance check R1 and R2. R1 is the plate load for V1. If, for any reason, the plate voltage on V1 should rise, so will the plus voltage on the control grid of V2. This will reduce the bias. For example, if cathode resistor R3 for V1 should open, the voltage on the plate of V1 would rise to 180 volts. This would put a higher positive voltage on the grid of V2 and the grid would disappear faster than hot dogs at a picnic.

Emphasis and de-emphasis

At the FM broadcast station there is a boost given to the high audio frequencies. This boost is produced by a pre-emphasis network. At the receiver we must lower the treble end of the audio by the same amount that the radio station has boosted it. This is done by a de-emphasis network made up of one or more resistors and capacitors.

The time constant of the de-emphasis circuit must be 75 microseconds. To get the time constant of the R-C network, we multiply the value of resistance by the amount of capacitance. Since we can

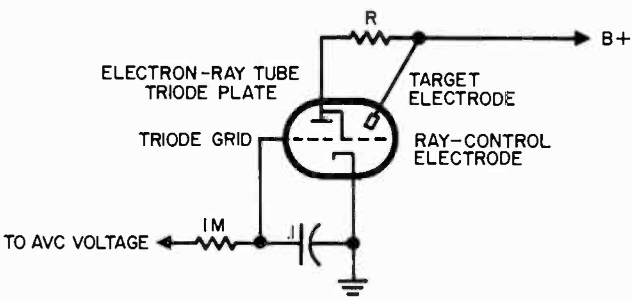


Fig. 820. *Indicator-tube circuit. Indicator tubes are often used with FM receivers or tuners.*

have any number of combinations which will give us 75 μsec, you will find many values used. De-emphasis circuits in FM receivers and in FM tuners are part of the detector circuit.

In Fig. 819 we have two such circuits, one for a discriminator detector and the other for a ratio detector. Actually, the type of detector circuit makes no difference. The product of R and C must still equal 75 μsec.

Trouble in the de-emphasis circuit

The de-emphasis circuit has so few components that we generally have no trouble with it. However, the innocent-looking de-emphasis circuit could make us reach for an aspirin. If the values of the de-emphasis components should shift, so will the de-emphasis curve. The result is frequency distortion. This could send you off on a wild-goose chase for some more likely or frequent cause of distortion.

Tuning indicators

How do we tune in an AM receiver? Just turn the dial until we get maximum sound and minimum distortion. With lower-cost receivers, though, we can't expect sound of too good quality. A good

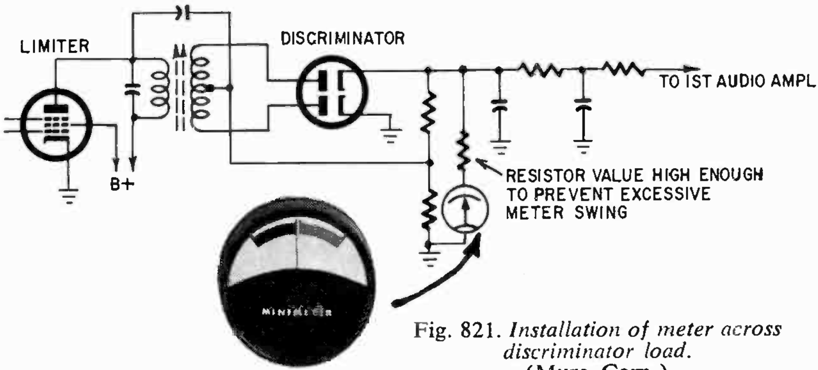


Fig. 821. *Installation of meter across discriminator load.* (Mura Corp.)

receiver or tuner is an expensive, well engineered device and the people who use them are inclined to be more fussy about the sound quality. For that reason you will often find tuning indicators included.

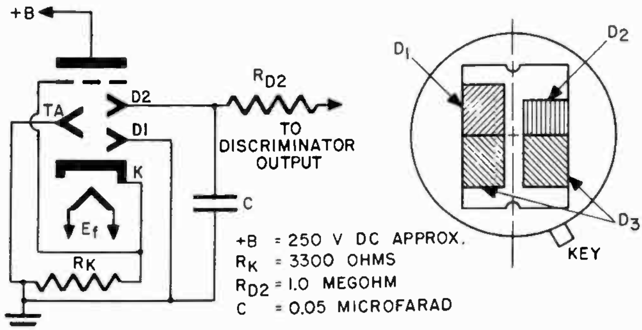
Fig. 820 shows a simple indicator circuit. The tube has a target area that glows when hit by electrons. The control grid of the triode section is tied into the avc line. When the avc voltage is less negative, as it would be for a weak signal, more current flows through the triode section, producing a greater voltage drop across resistor R. This puts a smaller voltage on the ray-control electrode, resulting in a shadow on the fluorescent area. When a strong signal is received, avc voltage is higher, less current passes through the triode section and as a result the voltage on the ray-control electrode goes up. More of the fluorescent area glows.

The receiver dial is adjusted until maximum glow area appears on the front of the indicator tube.

There are a number of types of indicators. Some are double indicators, others are single. They all work on the same general principle.

This is fine for AM reception where we tune for a maximum signal. FM is a different story. Tuning is for the center frequency at the discriminator or other FM detector. The simplest method, and often considered the best, is to connect a sensitive zero-center meter across the discriminator load with a series resistor as in Fig.

821. But meters were large and expensive for many years. A dual tuning-eye tube was developed to use in this circuit to give



PATTERN RESPONSE IN VARIOUS CIRCUITS

CONTROL VOLTAGE SOURCE	OFF CHANNEL (-)	ON CHAN. OFF TUNE (-)	ON TUNE	ON CHAN. OFF TUNE (+)	OFF CHANNEL (+)
DISCRIMINATOR					

Fig. 822. *Basic circuit of dual tuning indicator tube. Electron beam is spread by positive voltage and compressed by negative voltage applied to D2.* (Sylvania Electric Products Inc.)

discriminator tuning indication. The basic circuit in Fig. 822 supplies this indication by the change in the box pattern displayed.

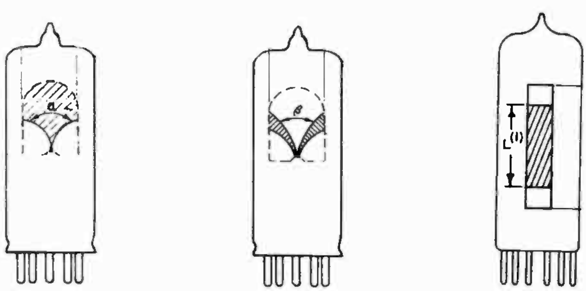
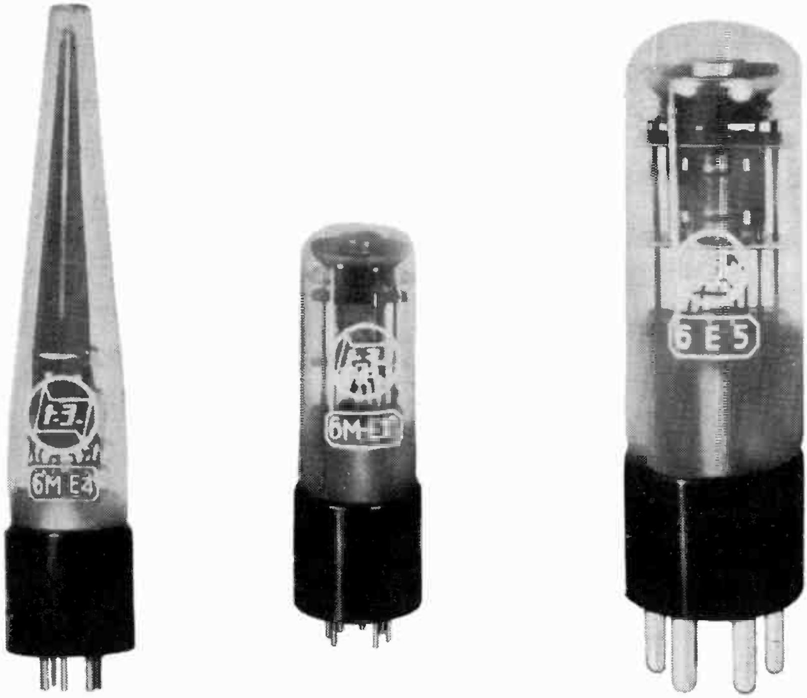


Fig. 823. *New indicator patterns are more appealing than the "cat's eye". Tube can be mounted directly on chassis, eliminating cables, extra connections and mounting hardware.* (Amperex Electronic Corp.)

The cost of meters has been reduced and their design made more attractive so they are now sometimes included as part of the eye-catching front panel of hi-fi tuners. In AM–FM stereo tuners,



Tuning indicator (electron ray) tubes are manufactured in a variety of sizes to make cabinet and panel design more flexible. One subminiature type moves along with the slide-rule-dial pointer. (Mura Corp.)

separate meters are often installed permanently across their respective detectors. There are no switches, no tubes, no resistors or capacitors, which partially offsets the extra cost of the meters.

Some cabinet designers and consumers consider meters too technical- or industrial-looking to be included in an entertainment device. So to please the consumer the tuning-eye was made smaller and patterns (Fig. 823) made more decorative and pleasing to the lady of the house.

QUESTIONS

1. What is the function of the afc circuit?

2. Name the two sections of the cascode amplifier. What are their functions?

3. Why are tuning indicators important to FM receiver circuits?

4. What stage usually precedes a discriminator? What does it do? How can you test it?

5. Where is the de-emphasis circuit used? What is its purpose? What trouble can it produce?

6. What are the major characteristics of a limiter stage?

7. What is a double detector?

8. Why is the cathode resistor of a cathode follower unbypassed?

9. What is the advantage in using a grounded-grid amplifier stage?

10. Describe the function of a converter in the front-end of a receiver.

CHAPTER 9

communications receivers

A COMMUNICATIONS receiver is to an ordinary radio set what a souped-up, streamlined, supercharged racer is to an automobile. Communications receivers are special. Designed to work with small-signal inputs, their sensitivity and selectivity are remarkable. Communications receivers are the royalty of radio.

How good is good?

This type of radio—the communications set—ranges from inexpensive types to those costing several thousand dollars. They are built with precision and skill. They contain circuits not found in ordinary radio sets. All of them cover quite a number of frequency bands, some ranging from 500 kc to 34 mc. Other sets cover the region below 535 kc, while others are designed to operate in the uhf, vhf and the microwave spectrums.

Some receivers are SSB (single-sideband), operate on both AM and CW (code reception). You will find dual conversion sets with a crystal-controlled oscillator, special filters, electrical bandspread, and a beat-frequency oscillator (bfo). Most of these receivers come equipped with an automatic noise limiter circuit.

Right now we are looking for the new features, new circuits. We've learned how to service if stages, but what shall we do if the if is different from those we learned about? What shall we do if the rf or the detector circuits aren't the kind that are familiar to us?

Examine these circuits, find out how different they really are. To be able to fix them, we must understand them.

Frequency range

Because the range of frequencies to be covered is so enormous, communications receivers switch coils in and out to cover various bands. In a typical set the bands might be something like this:

Band A	500 kc to 1.8 mc
Band B	1.6 mc to 4.9 mc
Band C	4.8 mc to 13 mc
Band D	12 mc to 34 mc

Band switching has its disadvantages. A band switch is a mechanical device. It can wear out, get dirty, get jammed. But when you pick a rose, you learn to watch out for thorns. If you get no recep-

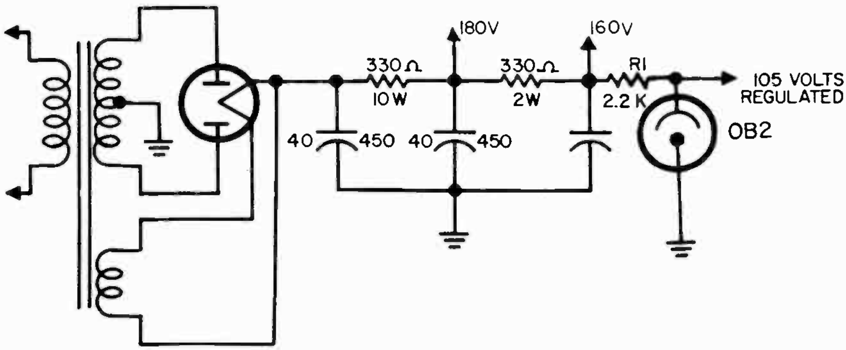


Fig. 901. *A gas tube is used as the voltage stabilizer in this power supply.*

tion on one band but the set works fine on all the others, you know enough not to go chasing around through the audio amplifier. Here the trouble could be in the switch or in the coils associated with that particular band. We know we're not plagued by tube trouble since the tubes work for all bands.

So what's new?

A communications receiver is a superheterodyne. Basically, it is a first cousin to the lowly ac–dc receiver although most proud owners of communications sets won't even mention their pride and joy in the same breath with an ac–dc set. But the relationship does exist.

Because of the similarity it won't be necessary for us to go through the communications receiver, stage by stage, but we will spend our time on:

(a) Completely new circuits.

(b) Circuits to which we have been introduced before but which have been designed to work in a different way.

Voltage stabilization

What happens when a current flows through a tube? Theoretically, at least, the current should remain steady until a signal comes along to disturb it. But unwanted plate voltage changes can also affect the current, not as much as the control grid, but enough to be annoying or disturbing. To avoid this we make the plate voltage regulation as good as we can.

For amplifier tubes in communications receivers, the regulation of the typical full-wave power supply is adequate. For oscillator

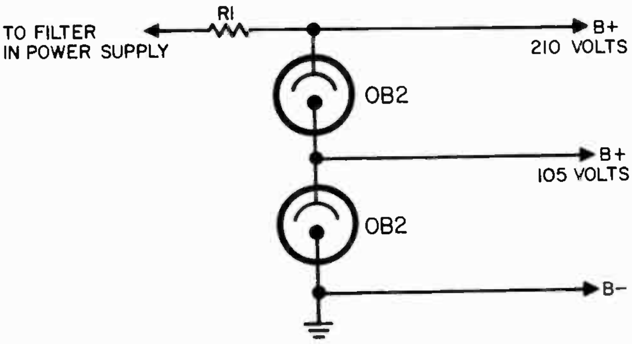


Fig. 902. *Regulator tubes can be connected in series to act as a voltage divider. A regulated voltage can also be obtained at the point where the two tubes are connected.*

circuits, though, somewhat better regulation is needed to remove one of the possible causes of oscillator drift.

An easy way of doing this is to use a gas tube in the power supply, as shown in Fig. 901. When the supply is turned on, the voltage appearing across the regulator tube is higher than 105. This drops to 105 when the gas tube "fires" or "ionizes". The tube then glows with a red or purple color (depending on the type of gas used in the tube). If the voltage at the plate of the regulator should try to rise, more current will flow through the tube, and a greater drop will appear across R1. Should the current through the tube decrease, the drop across R1 will decrease and the voltage at the plate of the regulator will rise.

How do we know if the regulator is working? If it is glowing, it is very likely hard at work. Connect your vom or vtvm to the plate of the tube, with the meter set to read 300 volts dc, full scale. The meter pointer should be absolutely steady. Now tune in a station, preferably one that will give a strong swing on the S-meter (if the receiver has one) or that will produce a loud signal. (You may have to set the band switch to the broadcast band to do this.) Once again, the pointer should remain steady at 105 volts. If it fluctuates, check the value of R1 and the B-plus voltage on the unregulated side of R1. If the resistance and voltage values are correct, try a new regulator tube.

The current through the gas tube depends on the type that is used, but on the average ranges from about 5 to 40 ma. The voltage at the plate of the regulator (when the supply is first turned

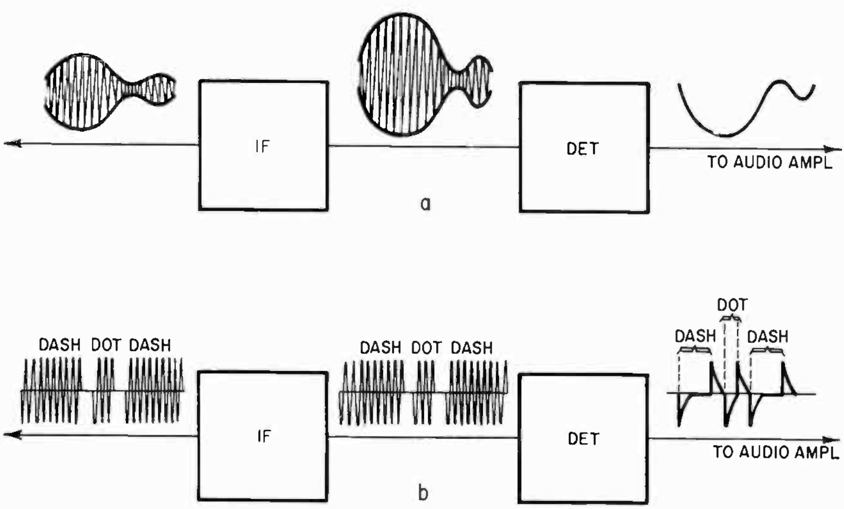


Fig. 903. *Audio modulation on the rf/ca if signal (a) easily passes into audio amplifier. Code transmission (b) has no audio and only start and stop edges of the code characters are passed on to the audio amplifier.*

on) must be higher than the value of regulated voltage, otherwise the tube will not "fire". To check this, connect your test instrument to the plate of the regulator tube. Set the meter to read 300 volts dc, full scale. In the circuit of Fig. 901, the meter pointer should swing up beyond the 105-volt point, and then, as the regulator fires, should drop back to 105.

Two regulator tubes can be put in series, as shown in Fig. 902 to get twice the regulated voltage. Since the tubes act as a voltage divider, a tap can be put at the point where the two tubes are connected.

Gas tubes are available which can regulate at as low as 75 volts. Others are manufactured which regulate 90, 105 and 150 volts. Make sure you use a correct replacement when you substitute new tubes. Regulator tubes in series need not be identical.

AM vs CW

Suppose we have an AM broadcasting station with everything going full blast, with one exception. No one is talking or singing into the microphone.

What does this tell us? Our first (and natural) reaction would

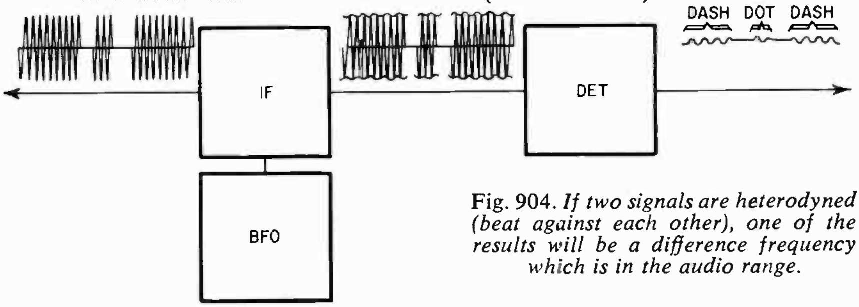


Fig. 904. *If two signals are heterodyned (beat against each other), one of the results will be a difference frequency which is in the audio range.*

be to say that nothing is being broadcast. But is that really true? We know that the carrier isn't being modulated, but what about the carrier itself? Why should it stop working just because the microphone isn't employed? So the station carrier goes on its happy way until it reaches the antenna of your receiver. Does it stop there? Why should it? And so it goes into the receiver, is changed into an if by a converter and then reaches the detector. Is this a stopping point? Again, why should it be? The carrier is rectified and then passes into the audio amplifier.

What is this rectified carrier? If the original carrier came from a broadcast station we know that it was transmitted within a certain frequency range. But our converter changes every station to a single, intermediate frequency. It is this intermediate frequency which is sliced in half by our detector. Suppose this frequency is 455 kc. (Remember–there is no modulation on it.) What can our audio amplifier do with that? And if some of this 455 kc could get through the audio amplifier, what could the speaker do with such a high frequency? And, finally, even if the speaker could possibly respond, our ears couldn't. At best, our hearing only goes up to about 20 kc.

Under what circumstances will we hear a signal? Only if the carrier is modulated—that is, if we change it in some way so that we can hear it (Fig. 903-A). Modulation is something that is usually done at the broadcast station, but we can modulate the carrier in the receiver.

We can make the carrier convey information by chopping it into longer and smaller pieces at the transmitter, but at the receiver we will need the cooperation of a special circuit known as a beat-frequency oscillator.

The bfo

Did you ever walk into a dark room after having been out in bright sunshine? For a minute or two you see absolutely nothing, and then, as your eyes begin to adapt, you manage to begin to see.

We can "adapt" our ears to the carrier with the help of a little electronic trick, shown in Fig. 904. In the receiver we have a

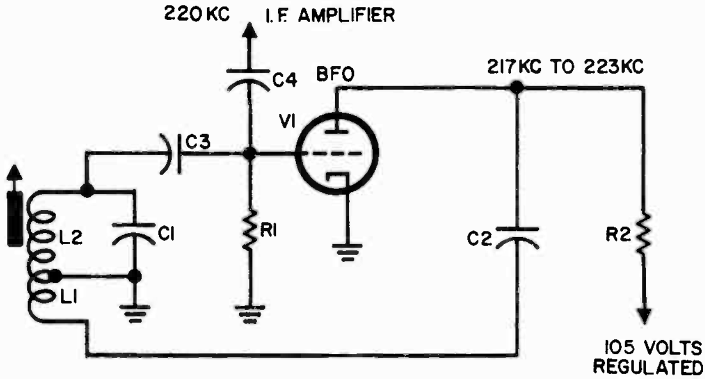


Fig. 905. *This bfo is a Hartley oscillator.*

circuit known as a bfo. This is an abbreviation for beat-frequency oscillator, a good name, because it tells us just what the circuit is supposed to do. The bfo generates a frequency which beats with the intermediate frequency signal in the receiver.

If the if is 455 kc, we could set our bfo at 456 kc (or 454 kc) and mix or "beat" the two frequencies. The output consists of a number of frequencies, but the one we are interested in is called the difference since it is equal to one frequency minus the other.

Let's see what a typical bfo looks like. The one in Fig. 905 is a Hartley oscillator. Feedback is through capacitor C2 to coil L1. L1 is part of the feedback circuit. C3 and R1 are the grid leak and grid capacitor and furnish bias for the tube. Note that the

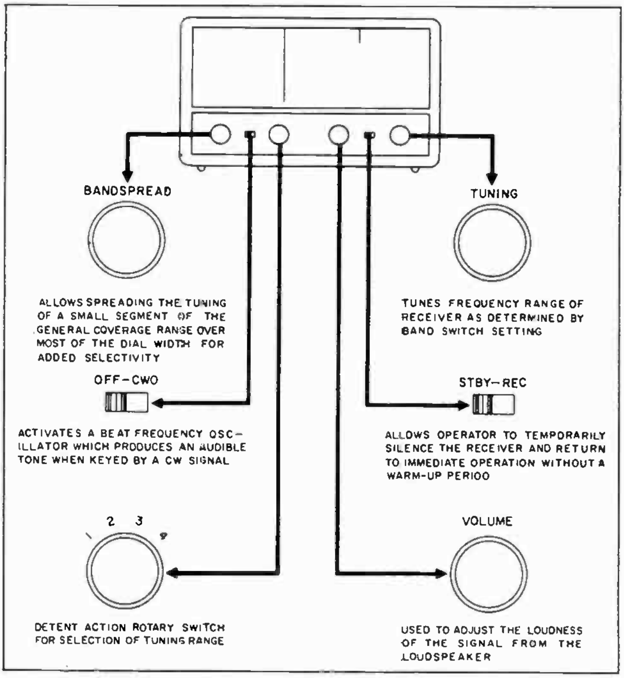


Fig. 906. *Communications sets have a large number of controls.* (National Radio Co. Inc.)

plate of the bfo is connected to a regulated source similar to that in Fig. 901.

When the receiver is turned on, the bfo will oscillate at a frequency set by the values of C1 and L2. Either C1 or L2 is adjustable so that the frequency of the bfo can be changed over small limits.

What are these limits? In the case of Fig. 905, our bfo will work in the range of 217 to 223 kc. If we set the bfo to 217 kc (its lower limit), the output from the if amplifier will be the difference between these two frequencies, or 3 kc (220 − 217 = 3).

Now suppose we set the bfo to its upper limit. What do we have then? Once again we will have a 3 kc output from the if (223 − 220 = 3).

This tells us that the maximum frequency of the audio tone we will hear will be 3 kc. We could set the bfo to hear any lower-frequency tone (such as 2 or 1 kc). When the bfo is at exactly the same frequency of the if (or very close to it) we will hear nothing.

Bfo troubles

We use the bfo only when our receiver is set to pick up CW. What is CW? This is an abbreviation for continuous-wave or code signals. This sort of signal consists of a carrier only, with no modulation. We need the bfo since, without it, it would be impossible to hear anything.

A switch on the front of the receiver is used to turn the bfo on and off. As a quick check, turn the receiver band-selector switch to the broadcast band and tune in a station. This signal will be modulated—that is, we will be able to hear speech or music. Now turn on the bfo by means of the bfo switch. You should hear a whistle. If you do not, turn the bfo frequency control slightly. If the set does not have a variable control, turn the tuning dial slightly. If you still do not hear a whistle, turn the tuning-range switch and pick up a code station. Try to select a strong station. You won't hear sound but, if two CW stations are close to each other in frequency, you may be able to heterodyne between them to get sound.

Suppose, though, your set works fine with speech or music but you are unable to hear code signals. Examine the power supply. Is the regulator tube conducting, as shown by a glow? Set your vtvm on the 300-volt dc scale and measure at the plate of the bfo. If you get no voltage here, move the test prod over to the plate of the gas tube regulator. Voltage here indicates R2 (Fig. 905) is open.

If you do get voltage at the plate of the bfo but it is much lower than the amount shown on the schematic, you have an indication that the tube (V1) isn't oscillating. When V1 oscillates (as it is supposed to do), it produces a negative bias (with the help of C3 and R1) which acts to keep tube current low. When the tube does not oscillate, a much larger current flows through the tube. This current passes through R2, producing a large drop across it, hence much less voltage remains for the plate of V1.

As another check to determine if V1 is oscillating, connect your vtvm between control grid and cathode (actually across R1). Set the instrument to read negative dc volts on its 10-volt scale. You should read several volts negative on the control grid. If not, the tube is not oscillating.

Failure to oscillate could be caused by lack of B-plus voltage, an open or excessively leaky feedback capacitor C2, a defective tube or a defective grid leak (R1) or grid capacitor (C3). Sometimes the slug inside coils L1 and L2 shorts the terminals. Broken, loose or corroded connections can also put the bfo out of operation.

If the bfo is working but you get no beat action, shunt C4 with a small capacitor. Any capacitor having a value of .0001 (10 $\mu\mu f$) μf or less will do. If this restores operation, C4 is open.

Controls

There is one thing you can say about almost any communications receiver and that is it usually has enough dials and knobs to keep any dial-twiddler happy. This doesn't mean they aren't needed. They most definitely are. But you should examine each knob and know just what each one is supposed to do.

Fig. 906 shows the controls on one type of communications receiver. There are six controls, some of which are fairly obvious, while others may require a few words of explanation.

Bandspread

Even with low-cost ac–dc receivers, there is no difficulty in

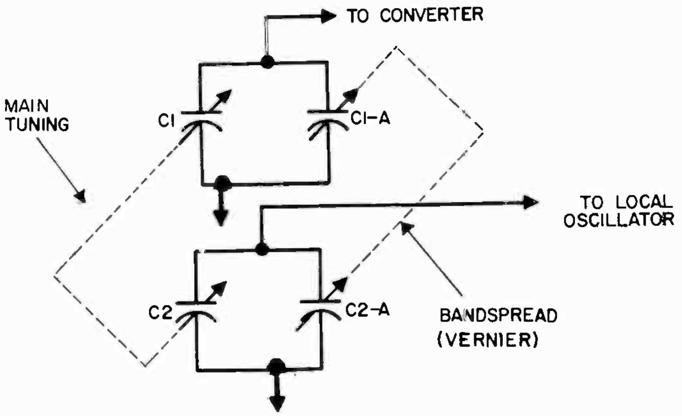


Fig. 907. *Communications receiver tuning and bandspread capacitors operate independently of each other.*

separating stations on the AM broadcast band. Receiver selectivity is good enough so that we can pick out each station easily.

On the broadcast band, though, each station is assigned a particular channel and a particular time for operation, and a limit on the maximum transmitter power that can be used. Other services on other channels must share frequencies and, as a result, two stations may be transmitting simultaneously on frequencies close to each other. This is especially true of code transmissions.

If two stations are very close to each other, we can use several methods of tuning them in. One would be to use a vernier dial so that rotation of the control would result in a very small motion of the tuning capacitor. A set of gears inside the vernier could take care of this for us.

Still another method is to shunt the main tuning capacitor with a variable unit having a much smaller capacitance. Thus, in Fig. 907, we see that the main tuning capacitors (C1 and C2) are shunted by variable capacitors (C1-A and C2-A). The main tuning capacitors are used to get as close to the desired station as possible. The band-spread units are then rotated until the station is tuned in. The tuning capacitors are ganged and are controlled by the main tuning knob. This knob also operates a dial indicating the approximate frequency of the station selected. The band-spread control operates the bandspread capacitors and its dial but does not change the main tuning dial setting as the vernier system does.

Tuning troubles

Because communications receivers cover quite a number of bands, often four or more, it is easy to decide if trouble exists in the front end. If all bands work except one, then the trouble is up at the front end.

Tuning capacitors bring their share of troubles. Look for plates that short or connections that are loose. Sometimes tuning-capacitor plates will touch only when the plates are fully meshed or close to it. The result is that the receiver will work well on stations from the middle- to the high-frequency end of a band but will be dead for stations at the low-frequency end.

If you get a scratching sound or if the set sounds noisy when you turn the main tuning control, look for mechanical defects. An ohmmeter check across the capacitor won't help since it is shunted by low-resistance coils. However, the stator is usually connected to the band switch by a single wire so it should be fairly easy to lift this temporarily. Disconnect at the capacitor end, rather than at the switch end.

Receiver analysis

Some communications receivers are fairly complex; others are much less so. Fig. 908 shows a type that covers broadcast and short-wave bands. This receiver covers four bands, selected by wafer switch sections. Note that the band-spread and tuning capacitors have the arrangement shown in Fig. 907.

This circuit has no separate bfo tube. Instead, the first if ampli-

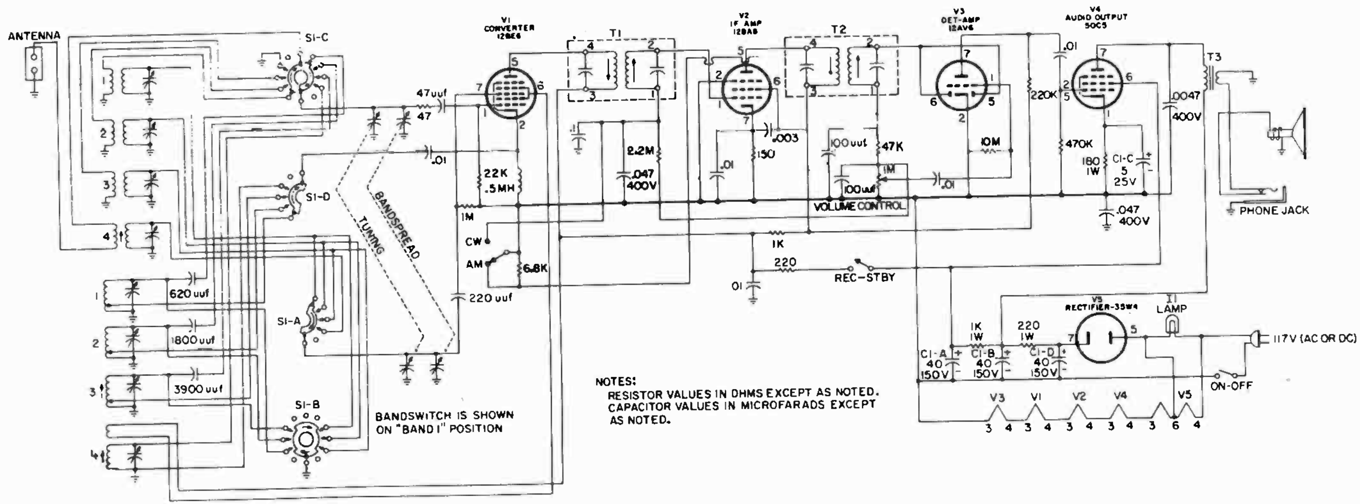


Fig. 908. *Simple type of communications receiver. Rotary wafer switches are used to select any one of four different bands. The set has bandspread tuning. Regeneration is used in the first if for CW signals.* (National Radio Co., Inc.)

fier tube is made to regenerate. When the single-pole double-throw switch is put in the CW position, we get feedback from the plate of the first if amplifier to its control grid. When the switch is put in the AM position, the feedback wire is grounded to the B-minus line.

A little earlier we mentioned the number of controls on a communications receiver. You can get some idea of the various knobs

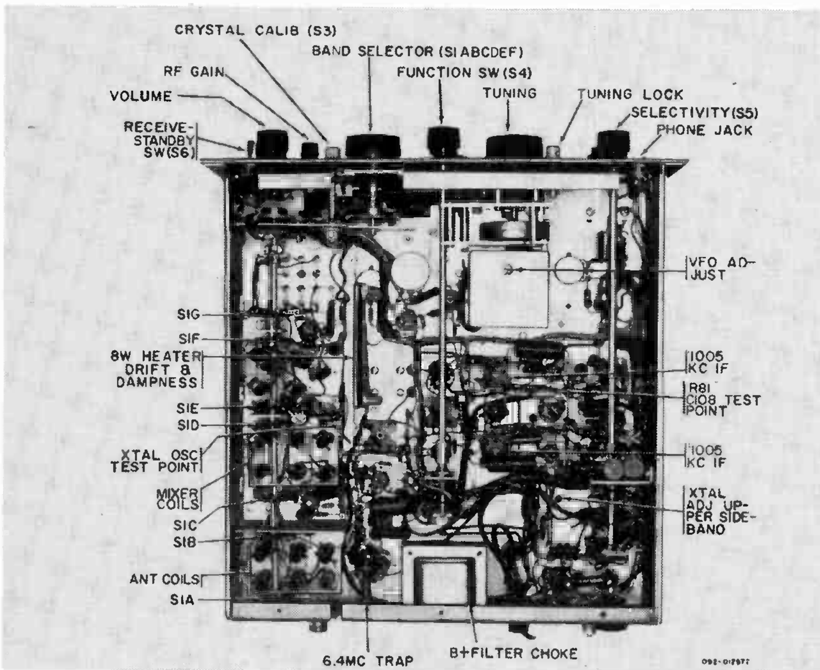


Fig. 909. *Communications receivers have many more controls and adjustments than the ordinary receiver used on the AM broadcast band. These must be made correctly if the receiver is to work as well as it should.* (The Hallicrafter Co.)

and switches by examining Figs. 909 and 910. Fig. 911 shows a communications receiver at work in a ham station.

Receiver construction

Some of the older communications receivers use point-to-point wiring, but the trend is toward the printed-circuit board. In some sets you will find a single board, but in the bigger receivers you may find two boards mounted on a metal chassis with cutouts provided for the boards. Small printed-circuit assemblies are mounted either on the main printed-circuit board or on a metal chassis. Fig. 912 shows the underchassis view of a communications receiver using several printed-circuit boards.

Calibrating the receiver

For some communications purposes, it is essential that the operator of the receiver know the frequency of a particular station.

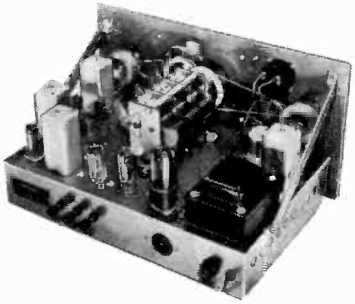



Fig. 910. *With 9 tubes and 10 controls this communications receiver chassis is not crowded. Speaker is in separate cabinet.* (Lafayette Radio Electronics Corp.)

One way of doing this is to tune in on stations whose frequency is known. US Bureau of Standards station, WWV, broadcasts on these frequencies:

2.5 mc
5 mc
10 mc
15 mc
20 mc
25 mc

Another station, WWVH, in Hawaii, operates on 5, 10 and 15 mc. Their broadcasts are characterized by standard tone frequencies and a time interval tick. Other information, such as ionospheric conditions, are inserted at scheduled intervals.

To calibrate the dial, it is necessary to pick up WWV on each of its frequencies since accuracy on one band in the receiver doesn't necessarily mean accuracy on another.

Some receivers come equipped with a means for plugging in a crystal calibrator. This consists of a 100-kc crystal oscillator. Power for the tube is taken from the receiver's power supply. The circuit for a calibrator is shown in Fig. 913. When the calibrator

Fig. 911. *Communications receiver being used in a ham station.*
(Allied Radio Corp.)

is turned on, it supplies beat notes every 100 kc. If calibration is very far off, the rf coils of the particular band being checked need realignment.

If the receiver you are checking does not have provision for crystal calibration, use an external calibrator. The trouble with a calibrator is that getting beats every 100 kc can be very confusing. You can use a 1-mc crystal calibrator instead, and once you have spotted points 1 mc apart on the dial, you can fill in by using a 100-kc calibrator.

For a short-wave listener, extreme accuracy won't be necessary. With the help of the calibrator you can make up a chart showing dial numbers vs frequency.

Troubleshooting the calibrator

The calibrator in the circuit of Fig. 913 has a small trimmer, C1. This will vary the frequency of the crystal enough to enable a zero-beat on WWV. If you get no zero beat, check the voltage at the plate of the oscillator. If it is much below the value specified by the manufacturer, the tube is not oscillating. Check bias and screen voltages. The trouble could be a defective tube.

Image rejection

In the usual superhet, a local oscillator signal beats against the incoming signal from the radio station to produce an if signal—

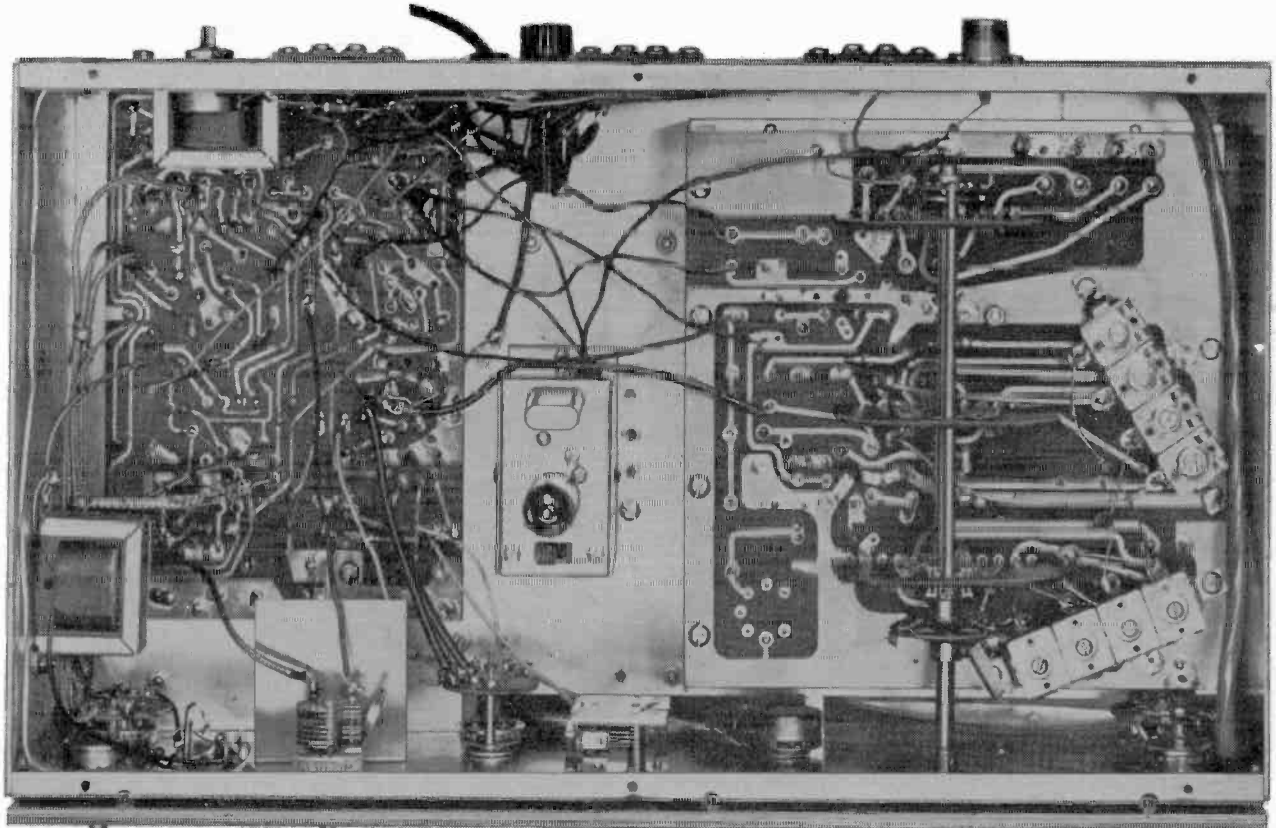


Fig. 912. *Communications receivers are often constructed with one or more printed-circuit boards.* (Allied Radio Corp.)

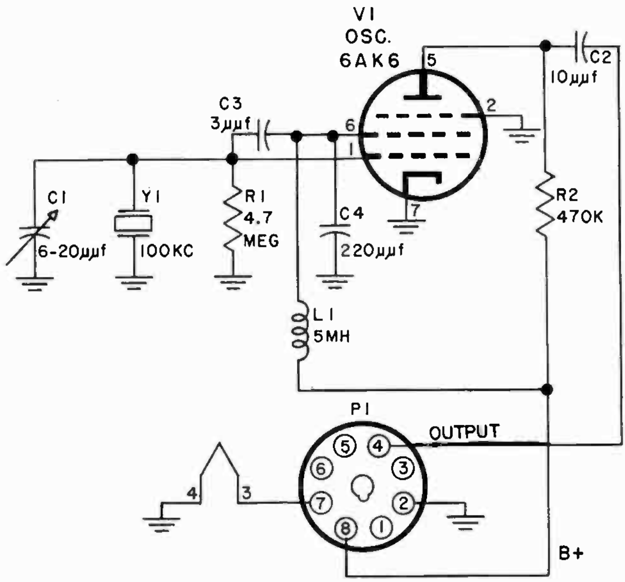


Fig. 913. *Crystal calibrator helps make the receiver a precision frequency instrument. (National Radio Co., Inc.)*

the intermediate frequency. Just as an example, suppose our incoming signal is 545 kc and our local oscillator at this time is at 1000 kc. Our intermediate frequency would be:

$$1000 - 545 = 455 \text{ kc}$$

Suppose, though, that at this time another radio station is transmitting on a frequency of 1455 kc and that it is sufficiently strong to force its way into our receiver, even though our dial isn't set for this frequency. What will our local oscillator do with this signal?

$$1455 - 1000 = 455 \text{ kc}$$

This is the sort of output our if stage likes, and so we now have two signals running through the if. They will both be amplified, detected and heard in the phones or speaker. It is true that the second signal, the one at 1455 kc, will be weaker, but it can be loud enough to be annoying. This second signal is known as an image.

The greater the number of tuned rf stages we have, the better is our chance for image rejection. Images on the broadcast band don't bother us too much, since, if they do occur, we just tune to a different station. But in a communications receiver we do not have a choice. The station we are listening to is the one that has a message for us.

Double conversion

Adding more tuned rf stages is one method for cutting down on images. Another is by using double conversion, as shown in the block diagram of Fig. 914.

The station signal is brought into the mixer, beats with the

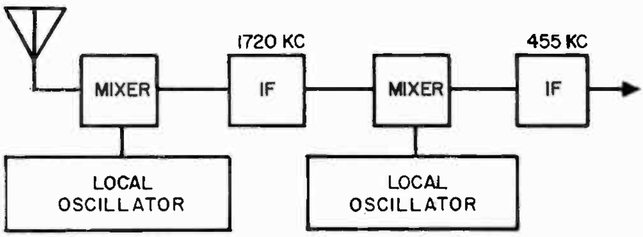


Fig. 914. *Block diagram of a section of a double superheterodyne reeciver.*

local oscillator to produce an if of 1720 kc. This if is then brought into another mixer where it is beat once again with an oscillator voltage, this time resulting in an if of 455 kc.

The if's used are selected by the manufacturer and vary from one receiver to the next. The choice of if's will even be different in various models of receivers made by the same manufacturer. In Fig. 914 the two if's are 1720 kc and 455 kc. In another receiver they could be 2215 kc and 230 kc. The first if could be any frequency from 1000 to 10,000 kc. You will find double if's, though, only in the more expensive communications receiver.

The higher the first if, the greater the separation between the wanted frequency and the annoying image frequency. The greater this separation the weaker the image signal voltage will be when it passes through circuits that are not tuned for it.

Checking the if's

In an earlier chapter we learned how to check the if stages of AM broadcast receivers. The same troubles that exist in those sets can appear in communications sets. There is a difference, though. The average AM receiver, especially the ac–dc type, is made to sell for a fairly low price and as a rule the components are seldom top quality. In the more expensive communications sets you will find a much better grade of parts.

What does this mean to us? Use the best components when making replacements. Even in communications receivers, parts can and do go bad, change value, dry out or weaken with age.

Most ac–dc sets are fairly alike in their general circuit design. Communications sets are more individualistic. Don't try to work on them without a circuit diagram. If a set is a double superheterodyne, you will need to know the two if's.

Although we show two local oscillators in Fig. 914, we do not want you to think that these are alike in every respect. The

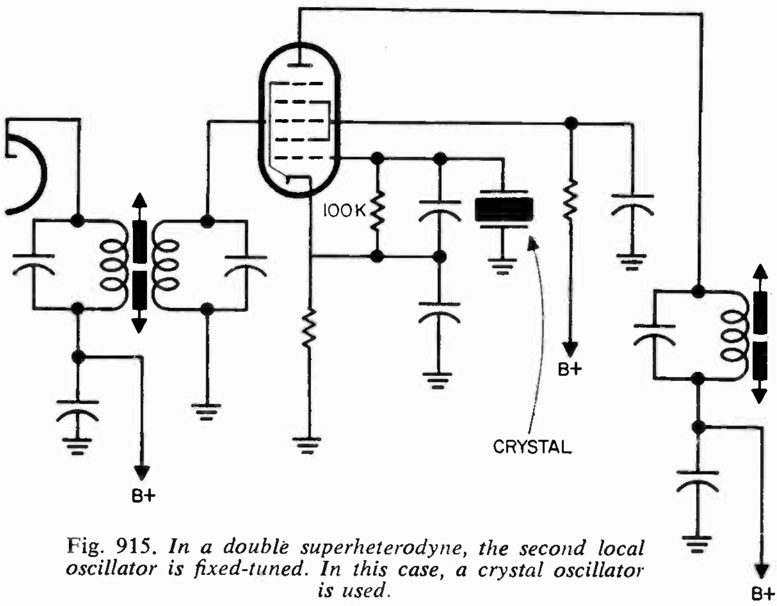


Fig. 915. *In a double superheterodyne, the second local oscillator is fixed-tuned. In this case, a crystal oscillator is used.*

first local oscillator is continuously tuned. This is necessary since we are going to pick up quite a variety of signals of all frequencies. The local oscillator must be tuned since its frequency must always be higher than that of the incoming signal. In the case of Fig. 914, the first local oscillator will always be tuned to a frequency 1720 kc above any incoming signal.

But what about the second local oscillator? It must beat with a frequency of 1720 kc. This frequency is the same regardless of the station being received. As a result, the second local oscillator can be fixed tuned and is often crystal controlled. In the case of

Fig. 914, the second local oscillator will be 2175 kc. This frequency, beating with the if of 1720 kc, will give us our if of 455 kc:

$$2175 - 1720 = 455 \text{ kc}$$

In Fig. 915 we have a pentagrid converter. This tube receives the if signal. One part of the tube, though, works as a crystal oscillator. With two signals going into the tube, one of the output frequencies will be the new if.

Antenna trimmer or compensator

"Once upon a time" is a good way to start any story and the story of radio is no exception. Once upon a time all radios used

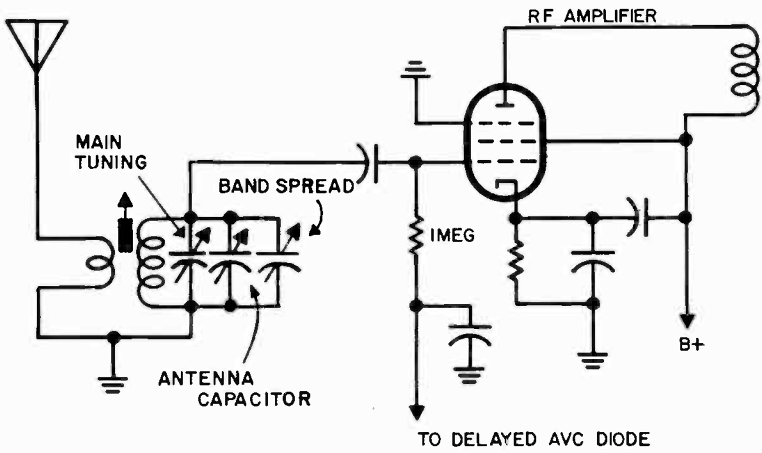


Fig. 916. *Antenna capacitor actually tunes rf amplifier. If antenna or lead-in is too long, excessive capacitance coupled to tuned circuit will detune it. With too short an antenna, the capacitance will be too little. The loading capacitor is used to increase or decrease the capacitance across the coil to compensate for the variation.*

outside antennas. As tubes were made to give more and more gain and the transmitters more powerful, the antenna got smaller and smaller, and, in the case of AM broadcast receivers, crawled right into the set.

For communications sets, though, we need a good outside antenna. An antenna is a broadly tuned circuit which can be "tuned" by changing its length. But a communications receiver covers such a very wide band of frequencies that it is impossible to have one antenna suitable for every wavelength.

We can change the "electrical" length of antenna in a number of ways. We can put a coil in series with it, as is often done in the case of auto radios. Another technique is to put a variable capacitor in series with the antenna or to connect a variable capacitor between one end of the antenna and ground. A variable capacitor used in this way is called an antenna trimmer—a good name since it does "trim" the antenna.

Fig. 916 and 917 show two antenna-trimmer circuits. The trimmer is mounted on the front panel of the receiver. Adjustment is simple. Tune in a station and then turn the trimmer knob until the signal is maximum. But you can do more than that. With the help of the trimmer an offending station can often be pushed into the background to minimize or eliminate the interference.

Very little can go wrong with this control. To see if it works,

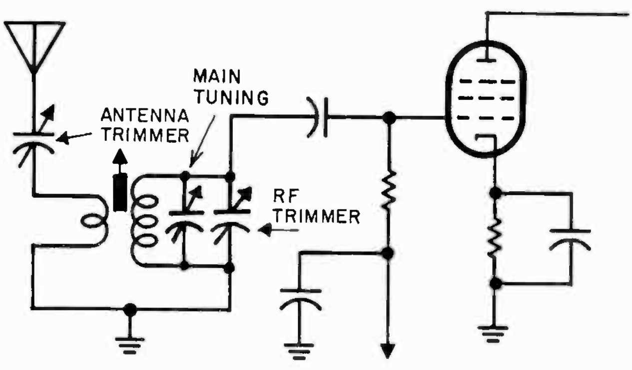


Fig. 917. *Antenna trimmer is also helpful in separating stations.*

tune in a station and then rotate the trimmer. It should have some noticeable effect. If it doesn't, check to make sure that someone hasn't disconnected it for some reason. The trimmer lead could be removed and the set still operate.

In Fig. 916, if the trimmer is shorted, signals will be killed on all bands. In Fig. 917, a shorted trimmer won't be noticed, except if you try to use the trimmer to improve the signal.

The circuit in Fig. 916 is used to compensate for the loading of the antenna capacitance on the rf tuned circuit. It also adjusts for slight variations in the tracking of the rf amplifier, mixer and oscillator tuned circuits.

The trimmer in Fig. 917 is more effective on the high frequency bands. Its effect becomes less and less noticeable as you approach the AM broadcast band.

Noise limiters

You might think that the life of a radio signal is an easy one. But the radio signal, like almost everything else, has competition. All sorts of noise voltages conspire to drown out the signal.

Noise can come from outside the receiver and also from inside. All sorts of devices have delusions of greatness and try to act as

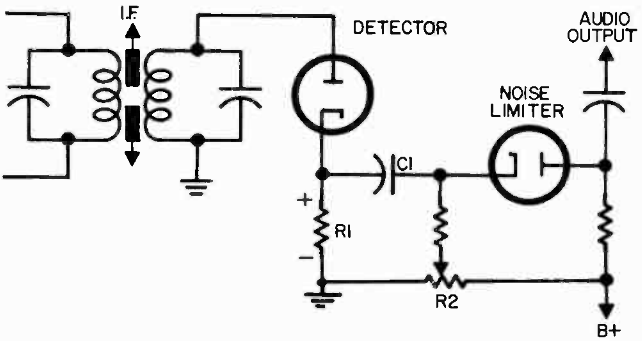


Fig. 918. *This noise-limiting circuit has to be adjusted for noise conditions. It is called a manual noise limiter (mnl).*

transmitters (and some of them do it very successfully). Motors with carbon brushes and other arcing contacts generate electrical noise. The well known offenders are neon and fluorescent lights, automobiles and electrical appliances such as vacuum cleaners, mixers, refrigerators, washing machines and elevators.

Inside the receiver, noise is produced as the current flows through components and past tube elements. Tubes, especially multi-element types such as pentodes and pentagrids are noisy. So, too, are gas tubes. Current flowing through resistors results in noise, although there are resistors especially designed to minimize this effect.

Poor connections, intermittent connections, corroded connections—all produce noise. A poor ground connection or an antenna and lead-in that flop around in the breeze produce noise. A washer can result in noise if, instead of making biting contact with a metal chassis, it makes poor or intermittent contact. Worn controls produce noise.

Finally, to add to this long (but by no means complete) list, Nature adds her own noise to our growing collection. Static, lightning, atmospheric conditions—all add up to more noise.

We admit the situation looks very bad, and sometimes it is, but before we hang a "for sale" sign on our communications receiver, let's see what can be done about the problem.

There are many types of noise-limiting circuits, one of which is shown in Fig. 918. The detector rectifies the signal, and the audio current flows through R1. The signal is resistance-coupled to the noise-limiter diode.

Note that the top end of R1 is positive and it is this varying positive voltage that is applied to the cathode of the noise limiter. Ordinarily a positive cathode would cut off the diode, but a B-plus voltage is applied to the plate. As long as this voltage is higher than the signal put on the cathode, the noise limiter will conduct and the signal will be transferred to the next stage.

Suppose, though, a noise pulse rides right in with the signal, which, in its own nasty little way, it will do. If the noise pulse is big enough, it will make the cathode of the noise limiter more positive than its plate and the tube will cut off.

You will probably argue that this will kill the sound too, and you will be right. But, unlike man-made modulated signals, noise pulses usually come in short, separated bursts. The time that the diode is cut off is extremely short, not enough to give you the impression of missing audio.

Mnl vs anl

Some noise limiters have a potentiometer so that the point at which the noise limiter comes into action is under the control of the operator. There could be a variable resistor in the plate of the limiter so that its B-plus voltage could be adjusted. In the circuit of Fig. 918, the mnl (manual noise limiter) control is potentiometer, R2. Its setting puts a greater or lesser amount of dc on the cathode of the noise limiter.

Anl (automatic noise limiter) refers to a noise-limiting circuit that does not require the attention of the operator. Some sets have a switching arrangement so that the operator is given his choice of anl or mnl.

Rf gain control

Did you ever eat a buffet dinner where you had to select different kinds and amounts of food to make up your meal? If the buffet is well organized, you may spend more time choosing your food than eating it.

A communications set has a similar sort of problem. It has a tremendous assortment of signals to pick from. You mightn't think that so bad, but the signals at the antenna range from those that are so weak that even a blood transfusion wouldn't help, while other signals are so strong that they would blast like dynamite if given half a chance.

Now that's exactly the point. Do we want to give signals a chance to do this? What about our automatic volume control? Isn't that supposed to protect us against very strong signals?

When a very strong signal comes in, our avc voltage is high. This avc adds to the existing bias we have put on the controlled

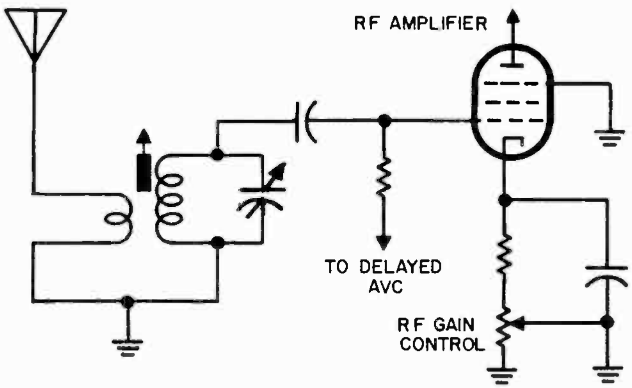


Fig. 919. *Rf gain-control circuit.*

tubes. A strong signal will make the total bias very high, driving the if tubes right into the curved part of their characteristics and causing lots of distortion. In other words, avc isn't a cure-all. It has its limitations.

There is a simple and easy way of getting around this problem, as shown in Fig. 919. All we do is put a potentiometer in series with the cathode of the rf amplifier tube. The control, now known as an rf gain control, supplies part of the bias for the tube. When the arm of the control is at the ground end, we get maximum bias.

What about avc for this tube? The tube still gets its avc voltage, but since the rf gain control has reduced the gain of the tube, the avc voltage will be much less than it would have been otherwise.

Checking the gain control

You can check the gain control in two easy ways. The easiest is to tune in a strong signal, vary the gain control and note the effect out of the speaker or on the S-meter. Another method is to set your vtvm to read low volts dc and connect it directly across the rf gain control. Vary the arm of the control and note the effect on the bias. There should be a definite change. Still another technique is to connect the vtvm between control grid and cathode and note the effect the gain control has on the overall bias.

Audio gain

On most communications receivers you will find a control marked afg (audio frequency gain). This is a volume control and you will find it where volume controls are usually connected . . . somewhere between the detector and the first audio. Volume-control troubles are no different from those in ordinary broadcast receivers. And, as in the case of broadcast receivers, the on-off switch is mounted on the volume control unit.

Phone operation

Communications receivers always have provision for earphone operation. Some sets have jacks for two phones; others just one. Fig. 920 shows a typical audio output arrangement.

The resistor appearing across the secondary of the output transformer makes certain that there will always be a load on the transformer. When the phones are plugged in, the speaker is automatically disconnected.

The speaker is a PM unit and, in many sets, is a separate item.

S-meters

People who use communications receivers are like sports car or boating fans. They take their fun seriously. They like to know everything that happens, everything that is going on in their particular hobby.

What does go on? A signal comes into the receiver. How big is the signal compared to others that have been received? The meter that tells us this is called a signal-strength meter or an S-meter.

Our next step is to decide just what sort of meter we should use and where in the receiver we should connect it. What about a dc meter hanging right off the avc bus? The dc voltage in the avc line is proportional to the strength of the signal. The stronger the signal, the more avc voltage we get.

But is it practical? What if our receiver has delayed avc? Or what if the signal being received is so weak that it does not have the strength to give us enough avc voltage to more the meter pointer?

What do we need then? We need to put our meter in such a place that it will respond to small variations. We need a circuit such that we can take advantage of the sensitivity of the meter.

Fig. 921 shows just one of many possible S-meter circuits. The S-meter is connected between the cathodes of a pair of if tubes. One of the if tubes is avc-controlled—the other is not. When the set is turned on, current will flow through each of the cathode resistors. The S-meter adjustment control is rotated until the S-meter reads zero. At this time there will be zero voltage between the two connecting points to the cathode resistors.

Now suppose we tune in a signal. The avc-controlled tube will

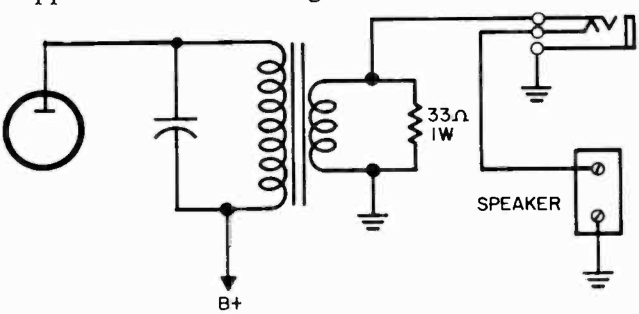


Fig. 920. *A load always appears across the secondary of the audio transformer. The resistor is needed since, with high-impedance phones, loading of the transformer will be inadequate.*

receive an avc voltage. The bias of the tube will be increased. What happens? The current through the tube is decreased and, as a result, the voltage drop across the cathode resistor becomes lower.

But what about the other if tube, V2? It is not affected by the avc voltage and as a result its bias doesn't change. We now have our S-meter connected between two voltage points, one of which is at a higher voltage than the other. We know the result. Current will flow through the S-meter.

How much current? Wouldn't you say that it depends on the signal? The greater the signal, the greater the avc voltage. This is exactly what we want, though, an indicating device that reads in proportion to the signal strength.

S-meter troubles

What can go wrong with the S-meter? Sometimes, accidentally, the meter will "pin"—that is, the pointer will slam over to one end upon strong signal reception and will be bent or jammed. Generally, this isn't a fault of the meter but of the circuit using the meter. The S-meter circuit isn't designed to prevent this from happening.

You may note that the S-meter pointer will move when you clean its glass or plastic covering with a cloth. This is normal and does not affect the meter. An S-meter is usually a fairly sturdy 5-ma movement. If it doesn't respond when you adjust the S-meter potentiometer, check it and any other series resistors. If you suspect

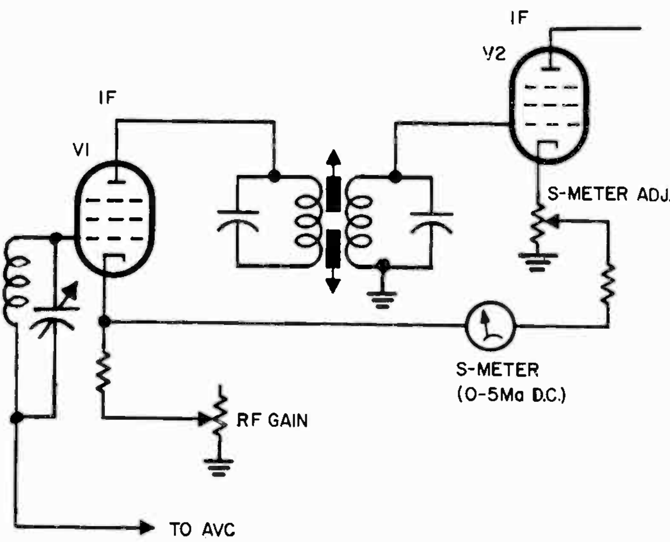


Fig. 921. *S-meter circuit. The S-meter must first be adjusted to zero by means of the S-meter potentiometer.*

the meter, disconnect its two leads and substitute the test leads of your vom, set to read low current. If your tester meter indicates when substituted for the S-meter there is no doubt that the S-meter has seen its best days.

Single side band reception

Did you ever have to chop or saw wood for a fire? If you did, we are sure you had the feeling that the fire had an enormous appetite and that you put in a lot of energy for very little heat in return.

When a carrier (at the broadcast station) is modulated, the carrier grabs the bulk of the power. Two-thirds of the power goes into the carrier, while the sidebands, like poor relatives, get what is left over.

Actually, when we modulate the transmitter, we only need the carrier at that moment. We can't transmit audio by itself. An audio signal wouldn't radiate very far. As a sideband, though, the audio signal has some of the characteristics of the carrier—one of them being its ability to travel through space with the greatest of ease.

So we do need the carrier, not for traveling purposes, but so we can modify our audio signal. Once we modulate, we can suppress the carrier.

This leaves us with two sidebands. This is a luxury. At the receiver we are going to throw away one of the sidebands, since the same audio information is contained in both of them. And so, at the transmitter, filters are used for suppressing one of the sidebands. A balanced modulator is used to get rid of the carrier.

What we are concerned with, though, is reception. The method used varies from one receiver to the next. The average avc receiver doesn't function with single sideband reception, so unless the receiver's instructions say so, turn the avc control off.

Your first step is to tune the signal in as carefully as possible, for maximum output as indicated by the speaker. Turn the bfo on. Adjust the bfo control back and forth very slowly until you hit a spot where the speech will come through clearly instead of sounding all mixed up. If you cannot get the sound so you can understand it, go back to the tuning dial and adjust it slightly on either side. If this improves matters, return to the bfo control for further adjustment.

Tuning of an SSB signal isn't quite like tuning in an ordinary signal. It requires a little experience and a lot of patience, especially if you aren't used to it.

Two other controls will need some attention. If the set has an anl control, turn this to the off position. Keep the rf gain control turned down.

One of the important factors in SSB reception is that the bfo (beat-frequency oscillator) should not shift frequency once SSB signals are coming through. You may have gradual slurring or distortion. If readjustment of the bfo brings the speech back in again, then the oscillator may be drifting.

In many sets the plate of the bfo gets its B-plus voltage from the plate of a gas voltage regulator tube. If the set has a regulator in the power supply, and you are troubled with drift or are unable to get good SSB reception, try a new bfo tube.

QUESTIONS

1. What is a bfo? How is it used in a receiver? How could you determine if it works?
2. Describe a method for calibrating a communications receiver.
3. What is an image signal? What causes it?
4. What is double conversion? Why is it needed? How does it work?
5. What are the advantages of an antenna trimmer?
6. Draw the circuit for a manual noise limiter and explain its operation.
7. A communications receiver has an rf gain control. How can you check this control for proper functioning?
8. What is an S-meter? Why is it used?
9. Describe a method for tuning an SSB signal.
10. What might be the cause of drifting in a bfo circuit?
11. What do the following abbreviations represent—CW; mnl; anl; AM?
12. What circuit or circuits should you check if a communications receiver works on all bands but one?

CHAPTER 10 marine receivers

HAVE YOU ever been lost? Really lost? It probably put you in the same position as the little boy who wandered away by himself. When he was questioned about it, he put it quite simply: "My Mommy is lost." He was quite right. He knew where he was. But he couldn't vouch for his mother.

We don't make a habit of getting lost for a very good reason. We have too many landmarks. Wherever you live, you have set up certain references. The name of your street, the light on the corner, the size and shape of certain buildings, a well known tree or fence—all of these, and many more, are used as landmarks.

But what happens when you get away from these familiar objects? If you travel by car, you use a road map and you keep a watchful eye for road signs.

If you own a boat, and if you stay in sight of shore, you can also use landmarks as a guide. However, most boat owners don't like the idea of being tied to shore any more than a lively "young 'un" wants to be tied to his mother's apron strings. Getting away from shore, though, can be dangerous, since, if you are completely surrounded by water, you may suddenly realize how much alike all water looks. Water makes a very poor reference.

A new job for radio

There are many ways of knowing where you are, but some of these methods are more or less crude. You might guess your position by looking at the sun, by using a compass or by estimating through a knowledge of the speed of your boat. It's much better to be sure!

A good technique would be to use your radio receiver, but before

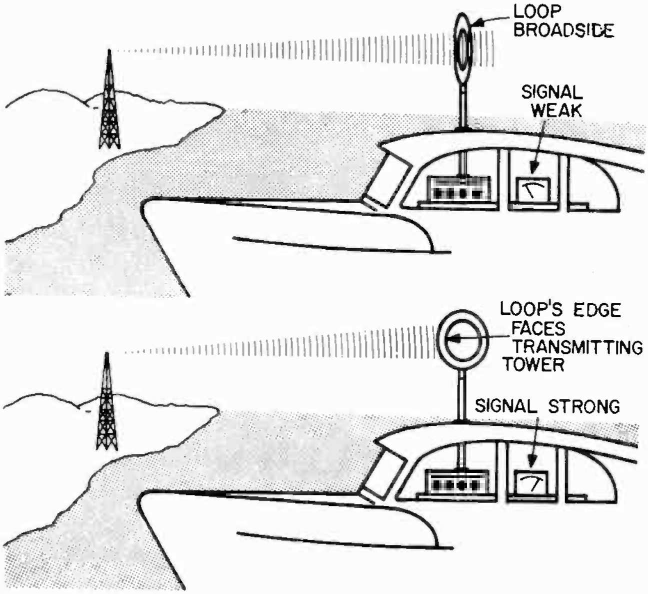


Fig. 1001. *The signal sounds loudest when the edge of the loop antenna faces the transmitting tower of the radio station.*

we do that, let's consider the loop antenna shown in Fig. 1001. When the loop is broadside to a station, the signal is very weak (or it may disappear completely). When one edge of the loop faces a station, the signal is strongest.

The marine receiver

Our purpose in talking about the loop antenna is simply to show one of the reasons for having a radio receiver on board. Frankly, a receiver is far more important on a boat than it ever could be in a car or home, since human life depends on it. Not only are marine receivers used for direction finding, but also for weather reports and as part of a two-way communications system with other boats and with shore stations.

What is a marine receiver? Probably any radio you take on board can be classified as such, for even a transistor portable can be used to get weather reports. But a true marine receiver is one that is designed especially to cover certain frequencies.

Marine frequencies

A special band of frequencies has been set aside for boat use, but

Fig. 1002. *Two-band transistor portable covers the standard AM broadcast band and the radio-beacon band.* (Zenith Radio Corp.)

this does not mean that other bands cannot be used. The AM broadcast band can be used for direction finding and also to take advantage of weather newscasts. In addition, boat operators can use the low-frequency band. This range, covering 150 to 500 kc (near the bottom end of the AM broadcast band), is known as the radio-beacon band. Some transistor portable receivers are known as two-band sets. They cover the broadcast band and also operate over the beacon band.

Fig. 1002 shows a two-band all-transistor portable radio being used as a self-powered standby navigation instrument. Instead of a loop antenna, the receiver has two ferrite, plate type antennas which supply the sharp null characteristic of an adf (automatic direction finder) loop. The receiver comes equipped with a switch which enables the operator to disable the avc.

How many bands?

Once a receiver is taken on board, it becomes a marine receiver. Some are more so than others. Fig. 1003 shows a lightweight port-

Fig. 1003. *Transistor portable covers nine bands and is useful for marine navigation* (Zenith Radio Corp.)

able that covers no less than nine bands, including the standard broadcast, government lf (low-frequency), aviation band, international short-wave and beacon bands. The receiver is tropicalized—that is, its components have been sprayed with a liquid which resists fungus, molds and corrosion found in highly humid and tropical climates. The case is made completely of metal to avoid pickup other than that supplied by the antenna. This adds to its value as a direction-finding unit since signal pickup is confined to the direction-finding circuits.

The beacon band

What sort of stations operate on this band? On this band you will pick up signals transmitted by lighthouses, lightships, Coast Guard stations, ships, airports, etc. Some of these transmit CW (continuous-wave or code) signals while others broadcast speech.

Since there are so many other bands and single-spot frequencies available, you may wonder why we should bother with the fairly low-frequency beacon band. The answer lies in dependability. The

AM broadcast band is satisfactory for daytime reception, but at night, at a distance beyond 15 miles, reception may not be steady or consistent.

The marine band

The marine band is another group of frequencies suitable for navigation. It covers the range from 1,600 to 5,000 kc.

Thus, many receivers made for boat operation cover the three bands we have described: beacon, standard AM broadcast, and marine. This is especially the case in sets that are designed to work as rdf's (radio direction finders).

Receiver circuitry

Marine receivers belong to the general family of superheterodynes. Just because a receiver is used on a boat doesn't make it anything special. There are some differences but, if you can service a home receiver, you should be able to do the same with a marine set.

One of the most important differences is right up at the front of the set. You will usually find at least one stage of rf amplification and sometimes you will find two such stages. Rf stages add to a receiver's sensitivity and its selectivity, but there is much more to it than just that. What we are looking for is dependability. It's like carrying a spare tire in the trunk of your car. It is possible you

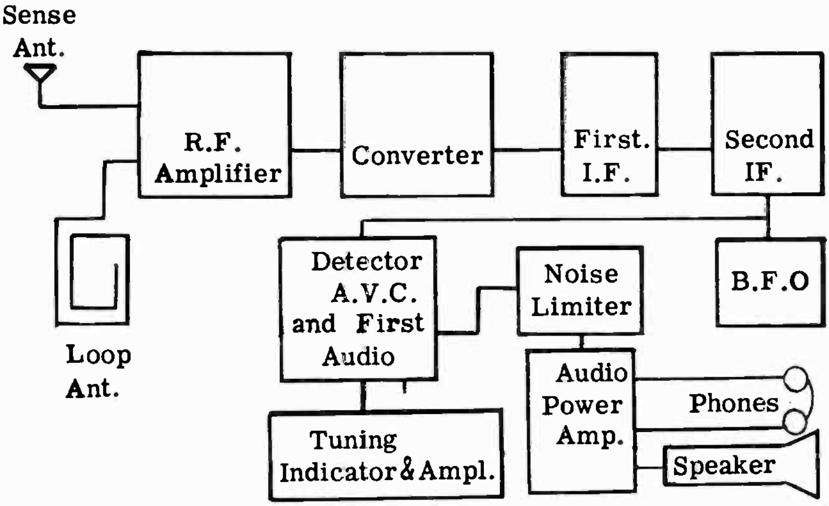


Fig. 1004. *Block diagram of a marine radio receiver.*

won't need to use it but it's a mighty comforting thought to know you have it along—just in case. With a marine receiver we don't want to hope to be able to pick up a particular station—we want to be sure. Also, stations that broadcast on the beacon and marine radio bands don't use the high transmitting power of standard AM radio stations, so we must make up for the difference at the receiver.

Fig. 1004 shows the block diagram of a marine radio receiver. We were about to say "a typical marine receiver" but is there really any such thing? You might have a typical ac–dc set, but marine

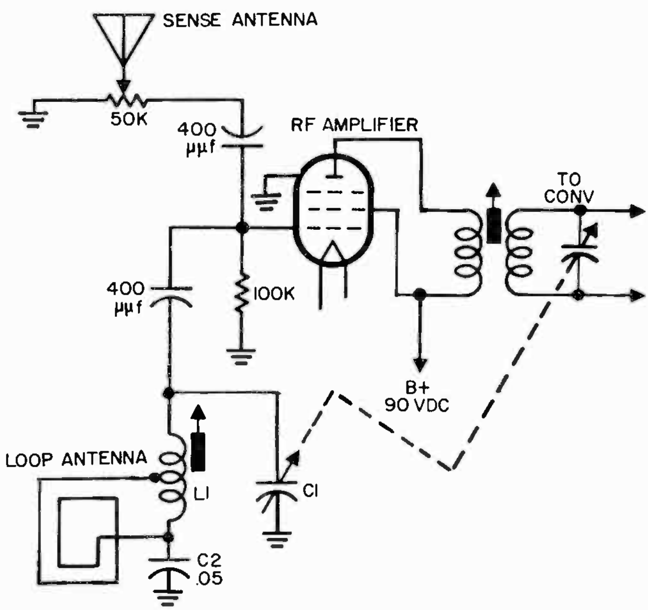


Fig. 1005. *Front end of a marine radio receiver. Two antennas are used for direction finding.*

radio sets depend a great deal on how much the customer is willing to spend. Some marine receivers are wonderful communications equipment in every sense of the word.

Now what about Fig. 1004? What is different about it? Stripped of its accessory circuits, we can see that it is an ordinary superheterodyne. It does have some interesting features. It has two antennas, one marked LOOP and the other marked SENSE. It has a beat-frequency oscillator (bfo) so that we can make code signals audible. It has a noise limiter and a tuning indicator. The tuning indicator has its own amplifier also.

The rf amplifier stage

A marine receiver rf amplifier stage is shown in Fig. 1005. Once we get over the shock of seeing two antenna inputs, we will realize that this is a fairly usual stage.

Antenna transformer L1 is tuned by C1. At first glance it might seem as though C1 couldn't do this, since L1 isn't connected to ground. However, the value of C2 is much greater than that of

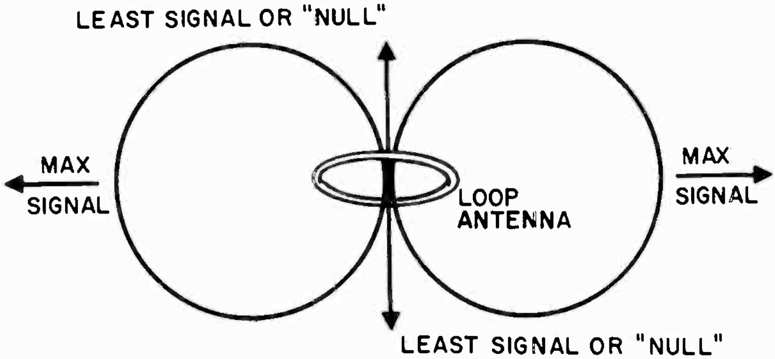


Fig. 1006. *Maximum and minimum signal positions of a loop antenna.*

tuning capacitor C1 so, as far as signals are concerned, C1 is shunted right across L1. The two antennas (sense and loop) are both coupled into the control grid of the rf amplifier. The amount of pickup by the sense antenna is governed by a 50,000-ohm potentiometer. The knob for this potentiometer will appear on the front panel of the receiver and will be marked SENSE.

Back to the loop

We started this chapter by talking about a loop antenna and now we are back to it again. The old-timers probably remember the loop antennas used on early sets and how often they had to adjust the loop to improve reception. And how often have you walked along with a portable receiver and found you had to turn it to keep from losing the station?

Fig. 1006 shows just what is going on. When the edge of the loop faces the transmitter antenna, we get maximum signal. Turn the loop just 90° and the signal drops to a whisper or disappears.

This is something like a pie for four hungry youngsters. We had better divide that pie into four equal sections. The same applies to a loop antenna. We can turn that loop through a complete circle or 360°. At two points on that circle we will get practically no signal or complete absence of signal. These are known as the "null" points. At two points on the circle we will get maximum signal.

We tune for minimum

What do we do when we tune a radio? Almost without thinking we adjust the dial until the signal comes in loudest. Now that is just what we don't want to do here. We adjust our loop antenna for a null, rather than for a maximum. There's a good reason for this. When we are direction finding, we're not so much interested in what

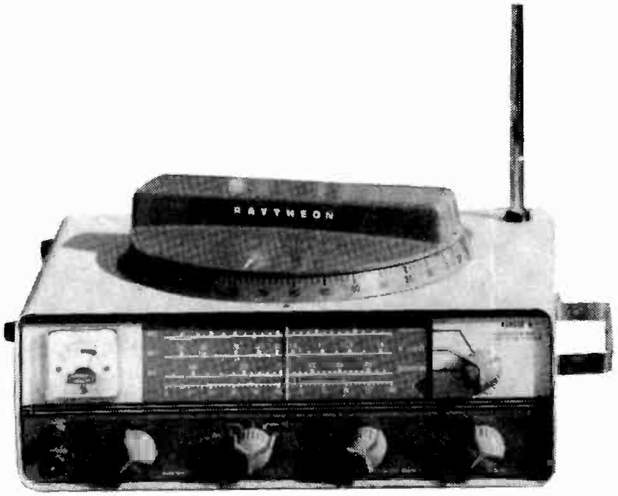


Fig. 1007. *This portable radio direction finder receives signals from long-range Consolan stations and standard broadcast bands as well as regular marine beacons. Sense antenna, right rear, differentiates between correct bearings and reciprocal bearings. Six standard flashlight batteries power the receiver. A dual purpose meter indicates battery strength and provides visual null reading for accurate bearings.* (Raytheon Co.)

the announcer has to say, as where we are. When we adjust a loop antenna for a null, we can do so quite sharply and accurately. It's much more difficult to tune for maximum signal since you can turn the loop antenna quite a few degrees on either side of the maximum point and not notice the difference.

Two nulls for the price of one

Suppose we turn our loop antenna (Fig. 1007) until we get a null point. We could turn the loop through half a circle (180°) and get another null. Where is the station then? Is it in front of us or behind us? It's like being on a straight road. We may know that the road goes north and south but, unless we have a road sign or some other indication, it would be just as easy for us to go in either direction.

Figure eight

You will see that the two circles in Fig. 1006 resemble the number 8. This figure-8 pattern tells us something about the behavior of a loop. Each half of it is the same. All that this means is that the

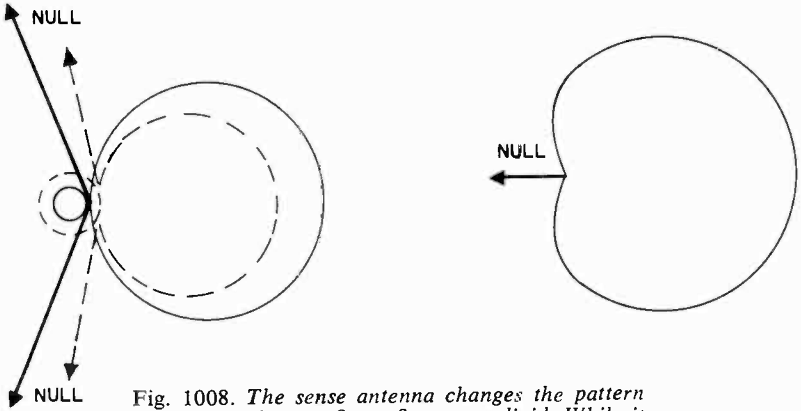


Fig. 1008. *The sense antenna changes the pattern of the loop from a figure-8 to a cardioid. While it would seem that extreme care of sense antenna adjustment would be needed to get a sharp null for direction finding when used with a loop, this is not so. The loop figure-8 pattern is used for getting the null and determining the two possible directions. The sense antenna is used only to pick the correct direction of the two and is not used for accurate direction-finding.*

loop can pick up a signal equally well in two positions. This is why the loop antenna by itself won't tell us whether the station is in front of or behind us. But suppose we make the loop antenna pick up better in one direction than the other, what then?

The sense antenna

Let s see how we can do this. Suppose we have a vertical rod antenna. The rod antenna has its own pickup characteristics and these are such that they will change the shape of our figure 8. This is shown in the drawings in Fig. 1008. To understand what is happening, suppose we go back to Fig. 1005 for a moment. In series with the sense antenna we have a 50,000-ohm potentiometer. This potentiometer controls the amount of signal pickup (by the sense antenna) that we couple to the control grid. By adjusting this potentiometer we can control the shape of the figure-8 pickup by the loop. As we turn the potentiometer, one half of the figure-8 pattern begins to disappear. At the same time, the null point changes its position in the loop. If we get a correct ratio of sense-antenna pickup to loop pickup, the figure-8 pattern changes to a cardioid shape. A cardioid pattern is heart-shaped.

Now what do we have? The illustration shows that we have signal pickup in one direction only.

Front-end troubles

In an earlier chapter we examined the troubles that could afflict an rf amplifier. The fact that an rf amplifier is used inside a marine

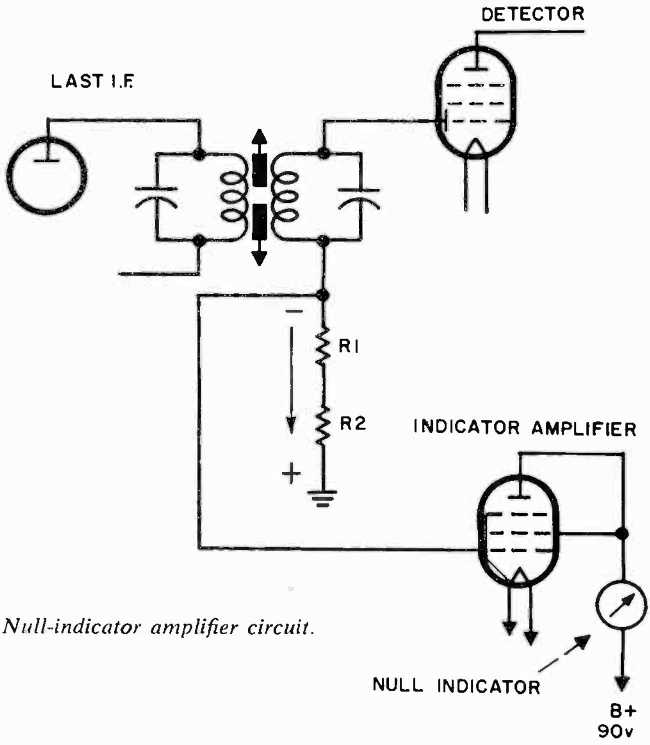


Fig. 1009. *Null-indicator amplifier circuit.*

receiver doesn't mean that it will not have the same troubles. It also has a few of its own. The loop of the marine receiver is a mechanical device. Sometimes the loop is a separate unit while in others the loop is part of the case. The loop must be turned to get the null. The loop may have slip rings and brushes to permit it to turn and yet allow electrical connection to the receiver. The rings must be kept absolutely clean. This can be done with any commercial cleaner lubricant.

The housing for the loop is made of metal but it is not a complete, unbroken enclosure. The shield for the loop is made of copper or aluminum. Somewhere along the housing you will find a bit of

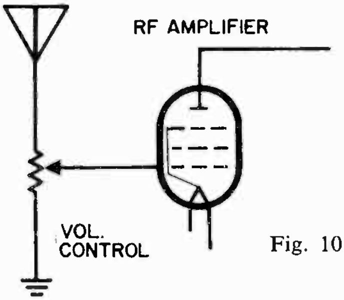


Fig. 1010. *Volume control in the rf input.*

insulating material. Make sure that this insulator is clean and free of dust. Some ambitious boat owners like to put paint on everything. If they get paint on this insulator, the loop will not work well or may not work at all.

Checking the direction finder

The direction-finder part of the marine receiver may be inaccurate for a number of reasons. The sense potentiometer may not be set correctly or it may be defective. To check on the direction finder or to verify its accuracy, tune in on a radio tower you can see, at the same time operating the rdf. Take bearings with the boat headed in various directions.

Null-indicator circuit

How can we tell when we have managed to reach the null point? We could listen to the receiver with a pair of phones or a speaker. But, unless we are operating a sailboat, there are going to be plenty of distracting noises. Generally, we pay very little attention to noise, provided it isn't above a certain level. But you can suddenly notice the slapping of water against the side of a boat if you're trying hard to pick the null—and this is true even if you're using earphones. Don't blame the instrument. That's the way our hearing is made.

To get around this difficulty, marine receivers come equipped with electronic null indicators. One type is shown in Fig. 1009.

To understand how this circuit works, suppose we are tuned to a strong signal and that the signal has been amplified by the if and presented to the detector. The diode will rectify the signal and a current will flow through the two series diode load resistors, R1 and R2.

What about the polarity of the voltage appearing across these resistors? That's easy enough to determine. Just looking at the arrow tells us that the top end is minus and the bottom end is positive. But the top end is connected to the control grid of our indicator amplifier tube. If we make the control grid negative enough (a strong signal will do it), very little current will flow through the indicator amplifier tube.

It's time we took a good look at the indicator amplifier tube. It's a pentode, connected as a triode. Measuring the combined screen

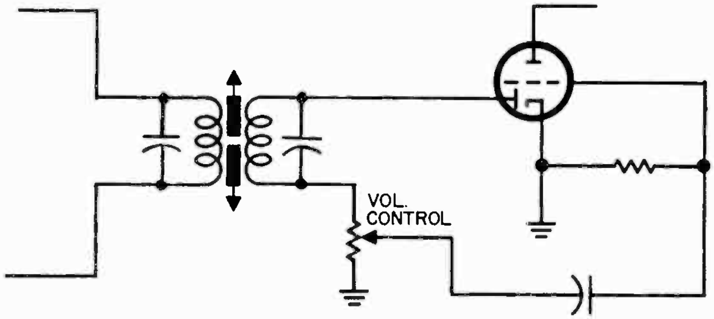


Fig. 1011. *Volume control works as the diode load.*

and plate currents is a dc milliammeter. At the present moment it is reading a very small amount because we have a signal at the detector's diode plate.

Now let's rotate our loop antenna toward the null point. As we do so, less and less signal reaches the diode plate. This means that less current will flow through R1 and R2. As a result, we put a smaller negative voltage on the control grid of the indicator amplifier tube. When this happens, more current passes through the tube and the pointer of our null-indicator meter starts to move toward the right. How to tune for a null? Keep an eye on the null-indicator meter and turn the loop until the meter pointer is as far to the right as possible.

By watching the null-indicator meter you can also tell if you have adjusted the sense-antenna potentiometer correctly. If it is set right, you will get only one forward movement of the meter pointer for a complete rotation of the loop antenna. Otherwise, for each rotation of the loop you will get two readings.

Null-indicator troubles

The null indicator is a simple circuit and easy to service. If you get no indication on the meter, try a new indicator amplifier tube. If that doesn't help, listen for the signal on the phones or speaker. If the signal comes through satisfactorily, then you know that the fault is in the indicator amplifier circuit.

Set your vtvm to read low volts dc. Tune the receiver to a loud

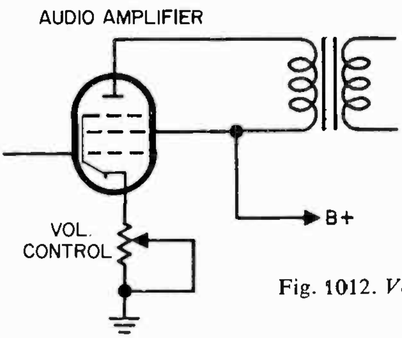


Fig. 1012. *Volume control in the cathode circuit.*

signal and see if you get a voltage drop across R1 and R2. If you get no voltage, check R1 and R2 for continuity. If you do get a voltage drop, substitute a meter for the null indicator. You can use your vom for this by setting it to read low milliamperes, dc.

Volume-control circuits

There is a big advantage in learning how a circuit works but there is a big disadvantage too. If we get accustomed to seeing a particular circuit, we get so that we can't imagine it appearing in any other way. Take a volume-control circuit. Most often we find it as part of the detector–first audio tube. But just because it is used that way regularly does not mean we cannot have our volume control elsewhere.

In Fig. 1010 the control is a variable resistor between the antenna and ground. The tube can be the rf amplifier or possibly the converter. Fig. 1011 shows the most common arrangement with the volume control acting as the diode load for the detector. In Fig. 1012 the volume control is the variable cathode-bias resistor for an audio amplifier tube. Another way of controlling the gain is by the method shown in Fig. 1013. Here the screen grid of one of the if amplifier tubes is connected to a voltage divider shunted across the B-supply.

Volume-control circuit troubles

Let's examine Fig. 1013 a little further. The plate gets almost the full 90 volts. The screen grid cannot reach 90 volts since there will be a voltage drop across the 100,000-ohm resistor.

What sort of troubles can this circuit give us? Unlike the volume control that is more familiar to us (Fig. 1011) the volume control of Fig. 1013 is a bleeder connected across the B-battery supply. This means that we will have a current flowing through the volume control—a current supplied by the battery. This current will be very

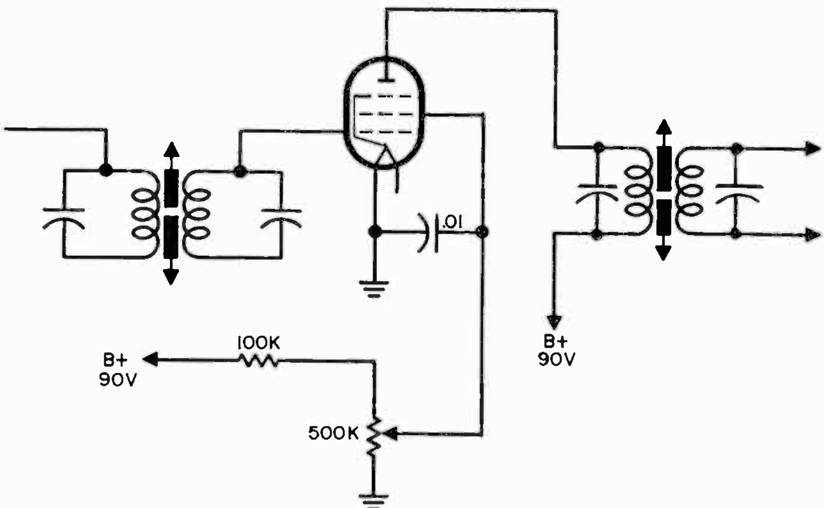


Fig. 1013. *Volume control in the screen circuit of an if tube.*

small—less than 1 ma. But it is enough to give us a voltage drop across each resistor, the 100K and the 500K.

Note particularly how the volume control is wired. In some volume-control circuits the center terminal and the ground terminal are wired together (Fig. 1012). We don't want this in the circuit of Fig. 1013 since we would then be grounding the screen for any position of the arm of the potentiometer.

To check the volume-control potentiometer, either turn the set off and make a resistance check, or, with the set turned on, measure the voltage drop across the outside terminals of the volume control. You should read 5/6 of 90 volts or 75 volts (since the volume control is 5/6 of the total resistance between 90 volts and ground).

If you get no voltage across the pot, make sure the battery is connected. Also measure the 100,000-ohm resistor for continuity. If the .01-μf screen bypass is leaky, the voltage drop across the 100,000-ohm resistor will be above normal and it will be difficult to control volume. The sound may be weak, depending on the exact condition of the capacitor.

Automatic noise limiter

What could be more peaceful than a smooth-running boat on a river or sea that is absolutely calm? Lucky for us our ears can pick

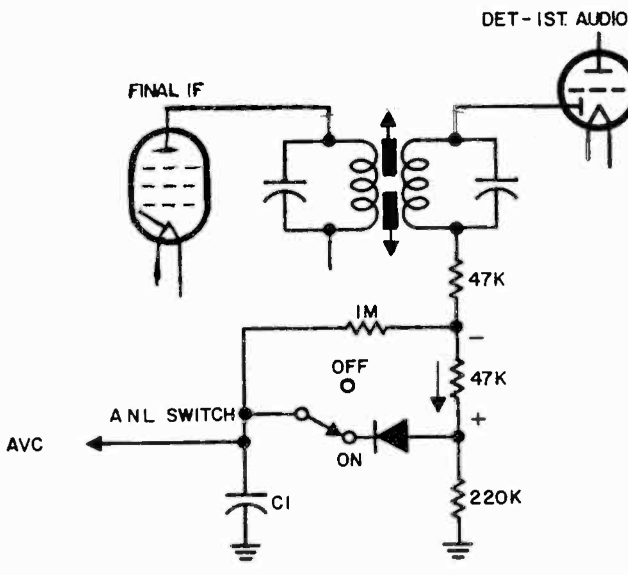


Fig. 1014. *Anl (automatic noise limiter) circuit.*

up only a limited range of sound. If our hearing were different, we might hear the electrical noise put out by the engine, the electrical noise radiated by motors on board, the static of a distant storm, the electrical noise produced when two metal parts of the boat rub against each other. We might also hear the electrical noise being radiated by our transmitter and being picked up and re-radiated by any bit of metal on the boat. All in all, the world is quite a noisy place and it is just as well that we have been provided with ears that can't hear everything!

Our receiver isn't that lucky! To the receiver, an electrical noise

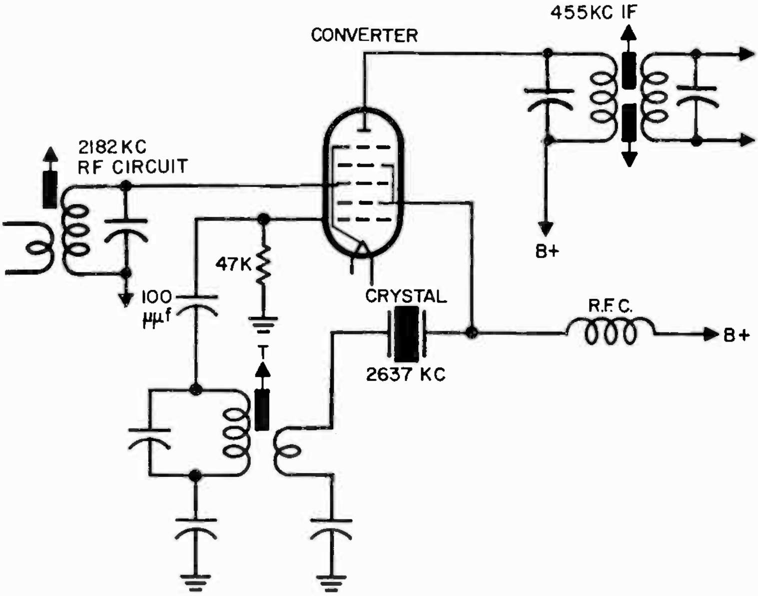


Fig. 1015. *Crystal control of the local-oscillator circuit.*

is a signal and, since the set is designed to amplify signals, that is exactly what it is going to try to do. You might think that the tuned circuits we have in the receiver would have enough sense to pass radio signals and block noise signals. They do the best they can, but some noise signals are so much stronger than radio signals they just bully their way through.

There are a number of ways of reducing electrical noise. One of these is using a noise limiter circuit, as shown in Fig. 1014. Here we have a crystal diode shunted across one of the decoupling resistors (1 megohm) of the avc network. When the anl (automatic noise limiter) switch is in the off position, the 1-meg filter is directly in the avc network. What happens when we put the anl switch in the on position?

Note the direction of the arrow through the 47,000-ohm resistor. The top end of the resistor is negative and it is this negative voltage that is applied to the grids of the controlled tubes through the 1-megohm resistor. Capacitor C1 is a filter in the avc line. The speed with which this capacitor gets charged depends on its capacitance and the amount of resistance in the avc line.

For normal signals the crystal diode does not get enough voltage to make it conduct. When a noise burst comes through, though, the diode conducts, effectively shorting the 1-megohm resistor, allowing a higher negative bias to be placed on the grids of the controlled tubes. Capacitor C1 also gets a chance to charge much more rapidly. C1, though, is connected to the grids of the tubes receiving the avc voltage and lowers the gain of these tubes for the duration of the noise pulse.

To check the anl circuit, try to pick up some noise deliberately. Note the difference as you work the anl switch back and forth.

Spot frequency operation

The international distress frequency is 2182 kc. The US Coast Guard has several hundred radio stations maintaining a constant watch on this frequency. Some marine receivers come equipped with tuned circuits permitting spot reception of this particular frequency.

Fig. 1015 shows how this is done. The band-switching arrangement has been omitted so that you can see the details of the circuit. The other bands would be the beacon band, broadcast band, etc.

The local oscillator, when switched to the international distress frequency, consists of a local-oscillator transformer and a crystal. Note that the crystal is made for 2637 kc. Since the distress fre-

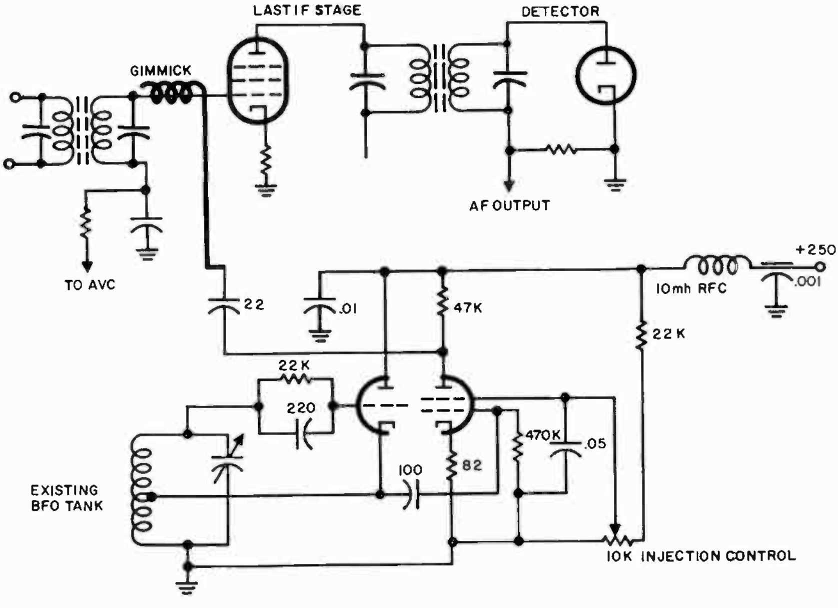


Fig. 1016. *Beat-frequency oscillator circuit.*

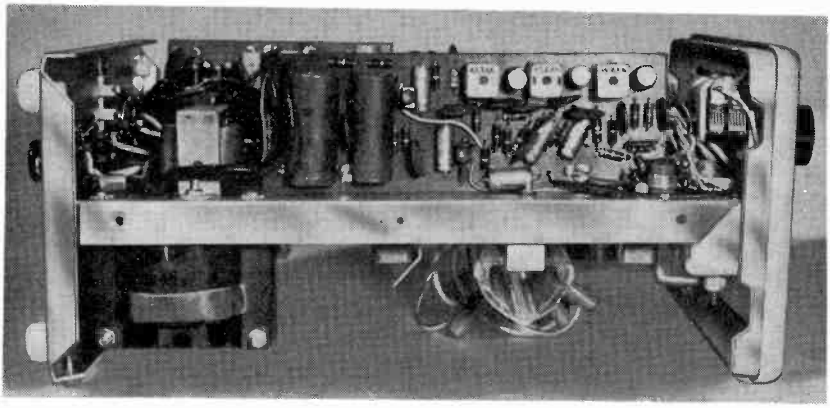


Fig. 1017. *Side view of transistorized receiver.*
(Bendix Radio Corp.)

quency is 2182 kc, the difference between these two frequencies is 455 kc (our intermediate frequency):

$$2637 - 2182 = 455 \text{ kc}$$

For all the other bands, the local-oscillator transformer is tuned by a variable capacitor. However, the distress frequency is not a band but is a single, fixed frequency. For this reason the local oscillator transformer can be fixed-tuned.

Now the big question is—why the crystal? Couldn't we just tune local-oscillator transformer T to 2637 kc? Wouldn't it work? The answer to that one is, yes, it would work. But could we always be sure that the transformer wouldn't get detuned? This could happen if the slugs rotated slightly or if the shunting capacitors changed their values. With a crystal in the circuit, however, the local-oscillator frequency remains fixed.

The purpose of the radio-frequency choke (rfc) is to keep the rf (2637 kc) out of the B-supply. At the same time we want a low-resistance B-plus connection to the anode grid of the converter.

Beat-frequency oscillator

You were first introduced to the bfo (beat-frequency oscillator) when we covered communications receivers. You'll find it turning up in practically all marine receivers since code transmission is so frequently used.

the use of radio receivers for communications and entertainment was a neck-and-neck race for a long time.

Today, though, radio receivers have gone way beyond their simple beginnings. Wherever you go, you are very likely to find a radio receiver at work. It could be in the pocket of a salesman getting orders by radio. It could be in a tractor out in the field. It could be in a lift truck in a factory. In our next chapter we are going to learn about some of the very special (and unusual) uses for radio receivers.

QUESTIONS

1. What is a sense antenna? How is it used?
2. What are the advantages of having one or more stages of rf amplification?
3. What is the marine band? What range does it cover?
4. What is tropicalization? Why is it used?
5. What is the beacon band? What range does it cover?
6. Why are two antenna inputs needed in a direction finder?
7. What is a null point? Why is it used in direction finding?
8. What is a null indicator meter? How does a null in-indicator amplifier circuit work?
9. Describe at least three volume-control circuits. Explain a technique for checking each one of them.
10. What is spot frequency operation? Why is it used? What sort of circuit is used to obtain it?
11. What is a gimmick? Why is it used?
12. Why are marine receivers designed to cover more than one band?

CHAPTER 11 mobile radio

Suppose someone were to ask you, "What is radio?" Sounds like an easy question, doesn't it? But is it as easy as it looks? What is radio? Is it just the little ac–dc set you have in your home? Is it just the little transistor portable you carry around with you? In short, can radio do more than provide us with entertainment?

Here are just a few of the places where you will find radio receivers: in trucks, tractors, police cars, ambulances, taxicabs, locomotives, in the pockets of physicians and salesmen, on fork-lift trucks, in repair service trucks, planes and missiles. What is the purpose of having radio receivers in such unlikely places? We can sum it up in just one word—communications.

When the engineer of a locomotive wants to get in touch with the men in the caboose, he does it by two-way radio. When a central office wants to talk to a salesman making his daily rounds, it notifies him by radio. A busy physician leaves his office but a little receiver in his pocket makes sure that he is always available for an emergency. A fork-lift truck operating in a remote corner of a big factory gets its pickup instructions by radio.

Is it good business?

The average home radio set owner wants to get the best radio repairs at the lowest possible cost. Since many radio receivers are bought for a low price to begin with, the amount that can be charged for servicing has a ceiling put on it immediately. Very often this works to the service technician's disadvantage since he is then unable to get a fair return for his labor.

But what about the much higher priced receivers used for communications? Companies using such receivers will expect to pay a reasonable charge, not only for repair, but for preventive maintenance. Here is a field in which a technician can build a steady, dependable business.

Mobile systems

A mobile radio setup is something like a telephone system. You have two people who want to talk to each other, or, at least, you have one person who wants to talk and another who must listen. One telephone could be considered the transmitter and the other the receiver.

Just about the most elementary mobile system you could have is shown in Fig. 1101. Here we have a transmitter located at some fixed point. We can call this transmitter the base station. We also

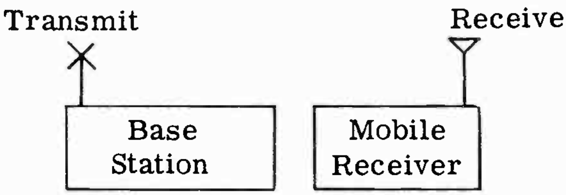


Fig. 1101. *Simple mobile communications system consists of a base station (transmitter) and a mobile receiver.*

have a receiver, but because this receiver can be moved (and is moved) from place to place, we call it a mobile receiver. Sometimes the receiver is in motion when it is being used—for example, a receiver in a taxi. Or, the receiver might be expected to pick up signals at certain times and certain locations. In either instance we call the radio a mobile receiver.

Mobile systems generally use quite a large number of radio receivers. Fig. 1102 shows a base station controlling three receivers but it is quite common for the base station to be in touch with 40, 50 or more receivers at one time.

The system shown in Figs. 1101 and 1102 is limited. The persons operating the mobile receivers can get instructions or orders, but they have no way of replying to the base station, other than using a telephone . . . and this might be inconvenient or impossible. For this reason, some mobile units are not only equipped with receivers but with transmitters as well. This, as shown in Fig. 1103, is really two-way radio.

There are other arrangements. In some cases there is no base station, but all the units can receive and transmit.

Frequencies

Depending on how it is to be used, mobile receivers work over a wide range of frequencies, all high. Typical ranges are 25 to 50, 152 to 162 and 460 to 470 mc and the Citizens radio bands of 27 and 450 to 460 mc. Others bands are available but are reserved for government use, aircraft work, etc.

Receiver operation

What is so different about a base station, say, compared to an ordinary broadcast station? A base station is not only equipped to transmit, but it is just as important for it to be able to receive.

At the base station we can have a complete transmitter (power supply, antenna, etc.), plus a complete receiver, with its own power supply and antenna, just as shown in Fig. 1104. The signal may be transmitted on one channel and the reply received on another, or all on one channel.

This system has certain disadvantages. Two separate power supplies are needed and also two separate antennas.

What other method could be used? We can borrow an idea from truck manufacturers. Did you ever see a truck with interchangeable bodies? Or a piece of furniture that worked as a couch during the

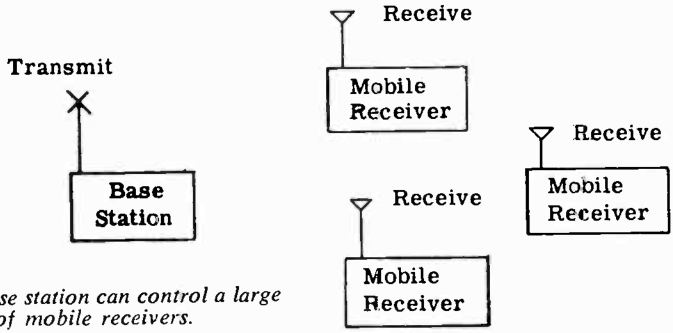


Fig. 1102. *The base station can control a large number of mobile receivers.*

day and as a bed at night? The idea isn't new. Only the approach is different.

Now let's look at Fig. 1105 to see how we get the arrangement we want. Here we have a transmitter and a receiver. Note the relay and the switch. The push switch is sometimes called a push-to-talk switch.

At the present moment the switch is open. This means that no current flows through the relay and as a result the armatures (there are two on this relay) touch their upper contacts. (The little inset drawing supplies some basic relay circuit details just in case you aren't familiar with the terms.)

What happens when the push-to-talk switch is open? The antenna is connected to the receiver and disconnected from the transmitter.

Look at the bottom armature. Right now it connects the receiver to the power supply.

When we want to reply, we press the push-to-talk switch. This permits current to flow from the battery through the relay coil. The relay coil becomes an electromagnet and attracts the metal armature. The bottom armature moves down. So does the top armature since it is linked to the bottom one.

What has happened? The antenna is connected to the transmitter (and at the same time becomes disconnected from the receiver.)

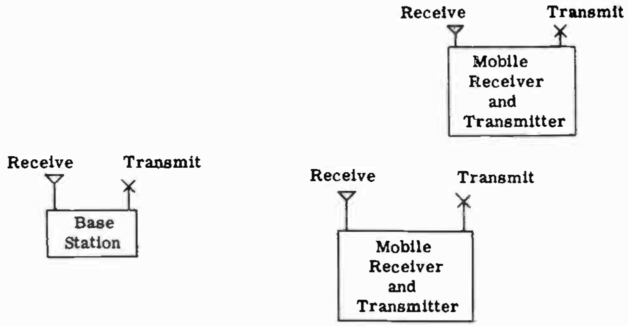


Fig. 1103. *In this system, all units, base and mobile, can receive and transmit.*

The power supply becomes connected to the transmitter and disconnected from the receiver.

Receivers for mobile use

What we have told you about so far is background information to give you some idea of what is meant by mobile radio.

What sort of receivers can we expect to service? As you might very logically expect, the receivers are superheterodynes. The word superheterodyne, as we learned in the chapter on communications receivers, covers quite a lot of territory.

We have a good idea of how a superheterodyne works. What we are interested in right now is not basic superheterodyne theory but rather in the circuit changes that have been made for this application.

AM or FM

Most (but not all) the receivers used in the vhf (very-high-frequency) and uhf (ultra-high-frequency) bands are FM. You will find some specially assigned mobile bands operating with AM.

Receivers for mobile work are fairly large. There's a double reason for this. The sets must work on high frequencies so extra circuits are needed to bring the if down to a reasonable value. Also, since the important factors are dependability and sensitivity, more rf and if circuits are used. Thus, some sets have from 10 to 20 tubes.

Double conversion

We have come across the double-conversion superheterodyne in our studies of communications receivers. What about mobile receivers? Fig. 1106 shows a block diagram of a typical unit. And what is (or should be) our first question? What's different about it?

Start right in at the front end. Our antenna is connected to an rf amplifier through coaxial cable. Here, working with high frequencies, ordinary wire just won't do.

There is at least one item about coaxial cable we should know and that is its impedance. The signal picked up by the antenna isn't the strongest in the world and, if we want it to have a chance to survive its slide down the cable to the antenna transformer, we

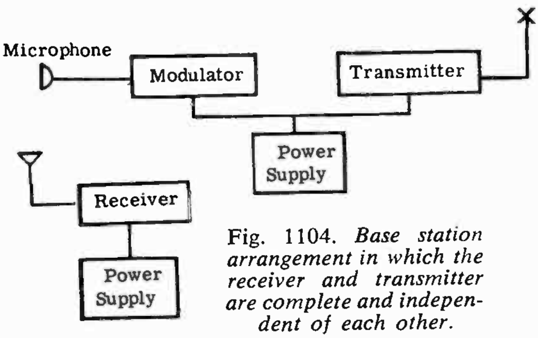


Fig. 1104. *Base station arrangement in which the receiver and transmitter are complete and independent of each other.*

must be sure to use the right type of cable. Its impedance should match that of the antenna and antenna transformer.

What can go wrong?

Coaxial cable is made of a conductor (a wire) surrounded by some insulating material. Around the insulation is a flexible metal sheath known as shield braid. The center conductor or wire is the "hot" lead while the shield braid is the "ground" connection. The shield braid is, in turn, usually covered with an insulating substance such as synthetic rubber.

It's difficult to expect that anything could go wrong with some-

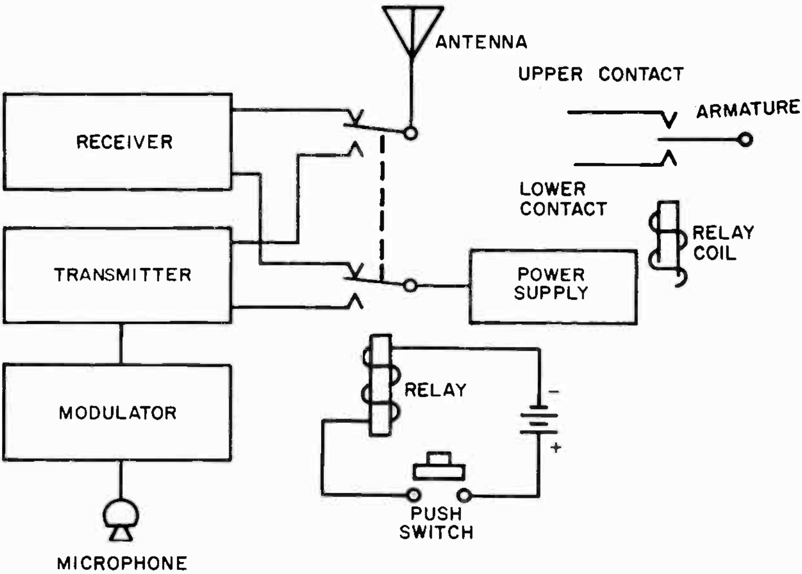


Fig. 1105. *Base-station arrangement in which a single power supply and a single antenna are used for receiver and transmitter.*

thing as well made as coaxial cable, but the passage of time has no pity on people or the materials that people make. If the cable has been flexed severely, the center conductor can break. The shield braid itself is made of individual wires and sometimes these pull away and short to the "hot" lead. If this is a permanent short, the transmitter won't "load" and the receiver won't pick up. If the short is an intermittent one, both receiver and transmitter will behave erratically. Sometimes the units will work and sometimes they won't.

The front end

Still working with Fig. 1106, let's move down the transmission line (the coaxial cable) to the front end. Here we will find either one or two stages of radio-frequency amplification. Wiring, parts layout and components are critical since we are working with high frequencies. Mobile receivers use high-quality components, generously overrated and selected for maximum stability and minimum noise. No bargain basement parts are used.

From the rf amplifier the signal moves into the mixer. At this point we notice a few differences. The mixer receives a signal from an unusual sort of local oscillator.

Is it hard to recognize the local oscillator? That isn't too surprising since the local oscillator is crystal controlled. Its output is fed into a frequency multiplier. The mixer gets its local oscillator voltage from the frequency multiplier.

Suppose we examine the local oscillator circuit just a bit closer. Why do we need a crystal oscillator? And what is the purpose of a frequency multiplier? For example, our receiver is to pick up signals at 155 mc. Our set is hard at work in the band covering 152 to 162 mc.

What about our intermediate frequency? It can be any value that the manufacturer chooses, so let us settle for 20 mc, a nice round number. What is our problem then? We must change 155 megacycles to 20.

We could do this very easily by building a local oscillator to work at 175 or 135 mc. Thus:

$$175 - 155 = 20 \text{ mc}$$
$$155 - 135 = 20 \text{ mc}$$

If we selected 175 mc, we would be working "above" the incoming signal. If we decided to use 135 mc, we would be working "below" the incoming signal.

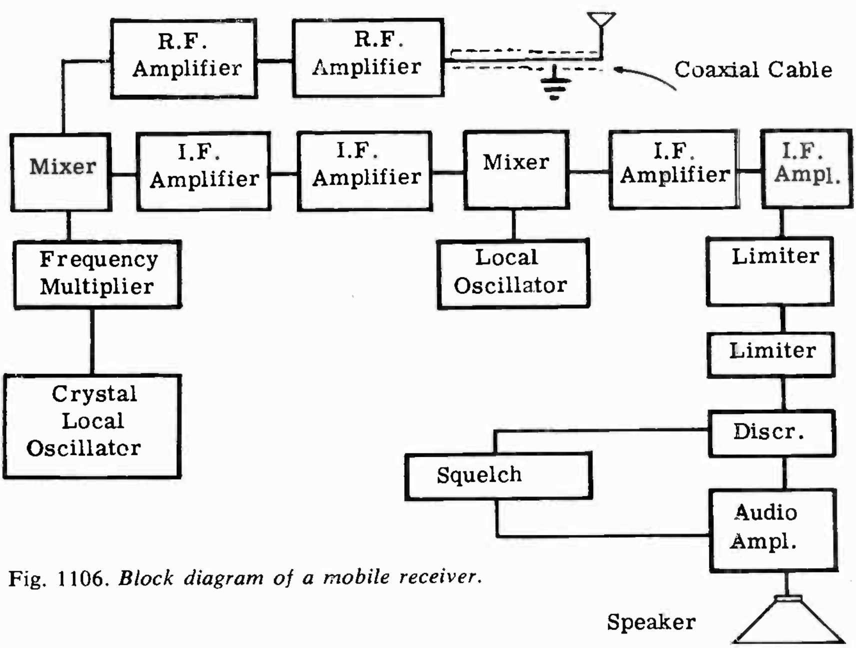


Fig. 1106. *Block diagram of a mobile receiver.*

What's wrong with that?

Here we have a good question. What's wrong with that? Tubes and parts are available which can be assembled into an oscillator that could work very nicely at either 135 or 175 mc. That's no problem.

The big problem is stability. As an example, what if we had a local oscillator and it worked at 1 mc. This is 1,000,000 cycles. Let us also say that our oscillator had just one bad habit—drifting. It would drift in and out of frequency by just one-half of 1%. Have we got a problem—or not?

To answer that question, let's change our percentage into other numbers. One-half of 1% is .005. When we multiply this by 1,000,000 cycles we get:

$$.005 \times 1{,}000{,}000 = 5{,}000 \text{ cycles}$$

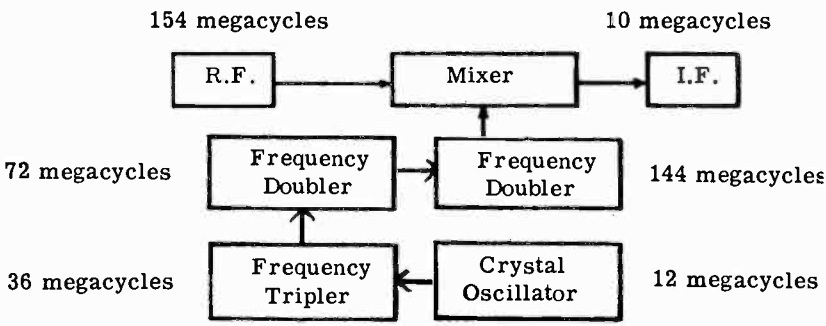


Fig. 1107. *The local oscillator has a crystal and a number of frequency multipliers.*

We might imagine that this is a large amount of drift, so suppose we apply the same sort of thinking to our local oscillator in the mobile receiver:

$$.005 \times 135{,}000{,}000 = 675{,}000 \text{ cycles}$$

Some difference! Just to give you an idea of how much of a drift this really is, think of the broadcast band. For the sake of round numbers, start at 500 kc and then add 675 kc (675,000 cycles to it). You will end up at 1175 kc, not far from the upper end of the broadcast band. In other words, a drift of just one-half of 1% is enough to shift the local oscillator in our mobile set a distance almost equal to half the length of the broadcast band.

Note that to make our arithmetic easier, we did not say a drift of plus or minus .005. If we had done that, then our drift would be twice the value we have given it. All in all, not a good situation.

How do we get around this problem?

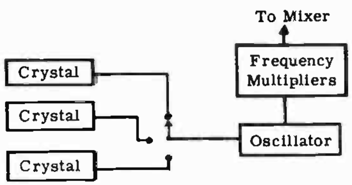
There are two ways of getting over a fence (other than opening a gate). You can prop a ladder against it and climb over, or you can dig a tunnel and crawl under. In the case of the local oscillator, we can make a fast trip downstairs (in terms of frequency, that is).

In Fig. 1107 we have taken the mixer circuit of Fig. 1106 and have expanded it a bit so that we can see what is happening.

Be fruitful and multiply

To make our arithmetic a little bit easier, let us imagine that our receiver is tuned to 154 mc and we want an if of 10 mc. We can start (as shown in Fig. 1107) with a crystal-controlled oscillator operating at 12 mc. The output of our oscillator is led into a frequency tripler. Since this circuit will multiply our local oscillator by 3, our tripler output is 36 mc. We then feed this frequency into

Fig. 1108. *Some mobile receivers have a switching arrangement so that any one of a number of crystals can be used. In other receivers the crystals are plug-in types.*



a doubler. This multiplies the frequency by 2, giving us 72 mc. By using another doubler circuit, we manage to get our local oscillator up to 144 mc.

Our mixer circuit is going to receive two signals. One of these will be the rf at 154 mc and the other will be the very much multiplied local oscillator signal of 144 mc. What is the result? Just this:

$$154 - 144 = 10 \text{ mc}$$

This 10 mc is our intermediate frequency.

You can't do that

It's probably a good thing we can't hear you, because if we were together we would probably be listening to some anguished shrieks, "You can't do that. A crystal oscillator is a fixed frequency. This means you can receive only a single, fixed frequency."

This is sad, but true. If you will think back to an ac–dc set on the broadcast band, you will remember that the local oscillator is tuned by a variable capacitor. This means that, every time we change the variable capacitor (when we tune the receiver), we change the frequency of the local oscillator as well.

The situation isn't quite so bad as it seems. The way in which we get around it is shown in Fig. 1108. Here we have a number of crystals connected to a switch. Now you might think that the local oscillator, adjusted to work on a particular frequency, might not like the idea of having crystals on three different frequencies. But these frequencies are very close to each other, so the oscillator circuit does quite well.

Is that good?

Does having the three crystals close to each other in frequency mean that we can tune only to a limited range? First, keep in mind that our crystal frequency is going to be multiplied (in this case) by 12 times (tripler-doubler-doubler) and so, while each crystal might be close in frequency, the final local oscillator frequencies will be well separated.

Note what this has done to us. We've paid a price for stability. With the arrangement shown in Fig. 1108, our receiver will pick up three spot frequencies in the 152- to 162-mc band. This might be enough for a particular operation using a mobile receiver. If not, more crystals can be used for the oscillator. In some sets, the crystals are plug-in types while in others a switching arrangement is used.

Back to work

In our detailed inspection of the front end we've wandered away a bit from Fig. 1106, so let's get back to it.

Following the first mixer we have from 2 to 5 if stages. The output of the if is then fed into another mixer which also receives a voltage from a second local oscillator. This local oscillator is fixed-tuned to some frequency slightly higher than the if. The output of the second mixer is still another if. For this second if strip we could use frequencies from 450 to 460 kc. However, any frequency can be selected by the manufacturer. A typical if would be 1500 kc.

The output of the if is fed through one or more limiter circuits, then into a discriminator type of detector and finally into the audio section. Note the use of a squelch circuit.

Thus, we have covered the signal arrangement of a mobile receiver. Now let's see what we can learn about some of the circuits.

Squelch circuits

Under most conditions of mobile operation, the receiver must be left on for long periods of time or else the receiver must come on at regular intervals. Typical examples might be in police cars, taxicabs or trucks where the operator of the vehicle must get messages at unexpected times. To be able to do this, the receiver must be kept on.

However, Fig. 1106 has probably given you the correct impression that mobile receivers have a tremendous amount of gain. As a result, noise voltages and weak signals have more fun with a mobile receiver than a mob of ants at a Sunday School picnic. To

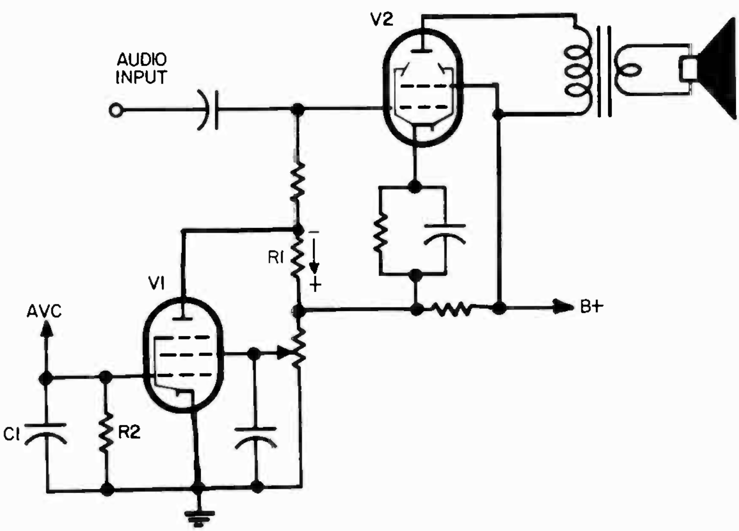


Fig. 1109. *Squelch circuit is used to mute the audio output in the absence of a strong signal.*

keep the operators of mobile receivers from investing their earnings in ear plugs, squelch circuits are used. A squelch circuit will cut off or will lower the gain of part of the receiver when there isn't enough signal present to listen to.

There are many types of squelch circuits and, to make the situation more confusing, they hide behind aliases. They are known as quieting circuits, silencing circuits, quiet automatic volume control (qavc), muting systems, and codan (carrier-operated device, anti-noise). But like a half-dozen young boys going out on a date, they all have the same thing in mind.

Fig. 1109 shows one type of squelch circuit. V1 is the squelch tube while V2 is the audio output power amplifier.

To see how the squelch tube has its hands around the throat of V2, consider the avc input to V1. When there is no signal input to the receiver or when there is a very weak signal, little or no avc

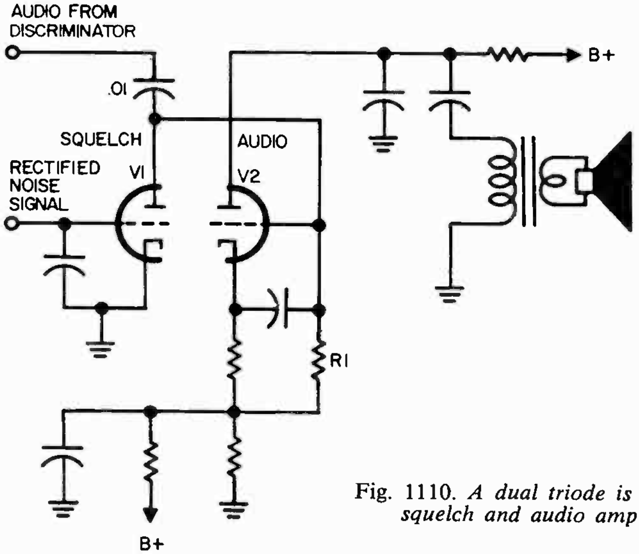


Fig. 1110. *A dual triode is used as a squelch and audio amplifier.*

voltage is produced. As a result, V1 runs hog wild since there is nothing to restrain its plate current. It has no bias on it and so the plate current of V1 manages to reach the top of its limit.

What will this current do? It will flow through R1 toward the B-plus end of the line. But when it passes through R1 we get a voltage drop across it, with the polarity shown in the circuit.

What is R1? We know it's the plate load resistor for V1. But what else? It has also managed to install itself very neatly between the control grid and cathode of V2. In this position it behaves as a bias resistor.

The voltage drop across R1 is fairly large and because of the polarity, V2 receives a hefty negative voltage on its control grid. The current through V2 becomes very discouraged and practically stops flowing. It's like having a policeman, a stop sign and a red light at a corner—all at the same time. V2, though, is the audio output tube, and, with no current passing through it, the only sound you will be able to hear in the room will be the heavy breathing of the base-station operator.

Now what happens when a strong signal arrives? V1 gets hit by a high avc voltage and, just to make sure that V1 doesn't go on and off like a movie neon light, we have R2 and C1 in the grid circuit. C1 charges to a steady dc voltage and manages to keep the control grid of V1 fairly constant.

Since the avc voltage is negative, the current through V1 decreases and so does the voltage drop across R1. This reduces the bias on V2 and current flows through V2 very nicely once again and once again sound fills the room.

Another squelch circuit

The circuit in Fig. 1110 looks quite different from that in Fig. 1109 but, basically, both work in a similar way. During the time no signal is being received, some noise voltage is developed at the output of the discriminator. This noise voltage is rectified and is

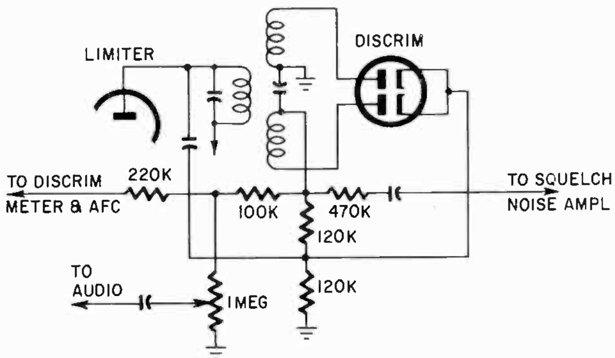


Fig. 1111. *Phase detector used in a mobile receiver. There are four types of FM detectors that can be used: the discriminator, the ratio, gated-beam and phase detectors.*

fed to the squelch tube, V1, as a dc control voltage. The polarity of this voltage is such that V1 conducts heavily. This current flows through plate load resistor R1. But R1 is also connected as a bias resistor between the control grid and cathode of V2. The polarity of the IR drop across R1 cuts off V2 and no signal is heard from the speaker.

When a signal comes in V2 is allowed to conduct and amplify the audio signal it gets from the discriminator.

Phase detector

For the most part, mobile receivers use a typical discriminator type detector. Unlike the ratio or the gated-beam detectors, this type does not remove amplitude modulation or AM noise spikes from the if signal.

Discriminators use one or more limiters to clip the AM that may be with the signal. Sometimes a phase detector, such as the one shown in Fig. 1111, is used. This circuit resembles the discriminator very closely.

The phase detector has two outputs. One is the audio signal, which can be fed into an audio amplifier stage (through the volume control). The squelch noise is supplied to a rectifier diode. The output of the rectifier diode is then sent (as a dc control voltage) to the control grid of the squelch tube.

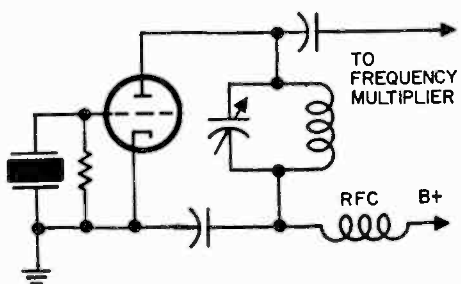


Fig. 1112. *In this circuit the frequency is controlled by a quartz crystal. The tuned circuit must be able to resonate at the frequency of the crystal.*

Crystal controlled oscillators

A crystal is just a bit of quartz that has been carefully ground to a certain size and shape. It is then placed between a pair of metal plates and the entire unit is enclosed. A pair of external pins connect to the metal plates. These pins are used for mounting the crystal into a socket.

The size of the crystal determines its operating frequency, but for the most part it is controlled by its thickness. The thinner a crystal, the higher its operating frequency. There is a practical limit to this since if you keep grinding the crystal thinner and thinner you finally end up with no material left to grind.

There is also another practical limitation. A crystal undergoes mechanical stress. The thinner the crystal the easier it is to pop it out of the realm of good working units.

Fig. 1112 shows a simple circuit using a crystal. The output of the crystal controlled stage can be capacitively coupled to the frequency multiplier (as shown) or it can be transformer coupled.

Another method of coupling is shown in Fig. 1113. Here we have a gimmick coupling the output of the crystal oscillator into the mixer. Where the receiver does not use frequency multipliers, the coupling can be made right to the grid of the mixer, just as in Fig. 1113.

The gimmick is shown as a coil. Actually, it works because of capacitive coupling, not inductive. In some cases there is no direct

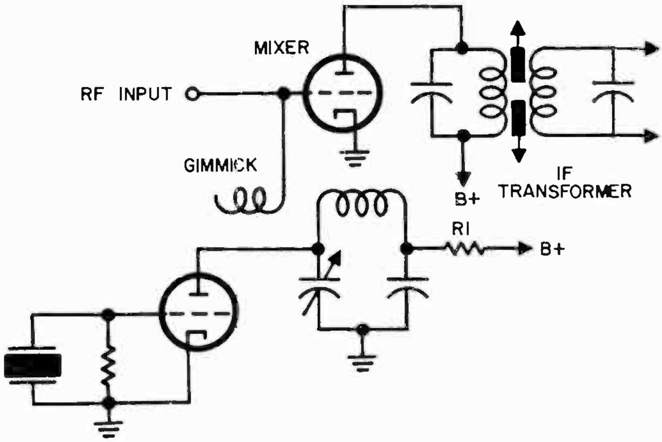


Fig. 1113. *In this circuit a gimmick is used to couple the output of the crystal oscillator to the mixer.*

connection at all. A few turns of well insulated wire are wrapped around the plate end of the oscillator coil. The other end of the wire is then brought over to the grid of the mixer (or the multiplier) and wrapped around the grid lead, or soldered to it. (Also see Fig. 1016 on Page 2-141.)

Fig. 1112 shows the use of a radio-frequency choke (rfc) to keep rf out of the B-plus line. Sometimes, as shown in Fig. 1113, a resistor (R1) is used. The choke is more effective and produces less of a voltage drop. The resistor is cheaper and easier to mount.

Checking the crystal oscillator

A bias voltage will develop on the grid of the oscillator tube if the circuit is working properly. Connect your vtvm between control grid and ground and check the amount of negative voltage on the grid. It will range between −3 to −10 volts, depending on the circuit. If you get no voltage reading, the circuit may be detuned or you may have the wrong crystal in position.

Another check method is to put a dc milliammeter in series with the crystal and measure the amount of crystal current.

Oscillator, multiplier and mixer

If you get a chance to look at the complete schematic of a well built, mobile receiver you might find it confusing – just at first glance. It isn't as bad, though, as some TV schematics. The best thing to do is to locate some familiar circuit and work your way out of the jungle from there. For example, you might look at the crystal oscillator, multiplier and mixer circuit, as shown in Fig. 1114. First, note oscillator coil L1. The notation, F1, alongside means that the coil is tuned to the fundamental frequency of the crystal. The coil has no tuning capacitor, its point of operation being adjusted by a slug.

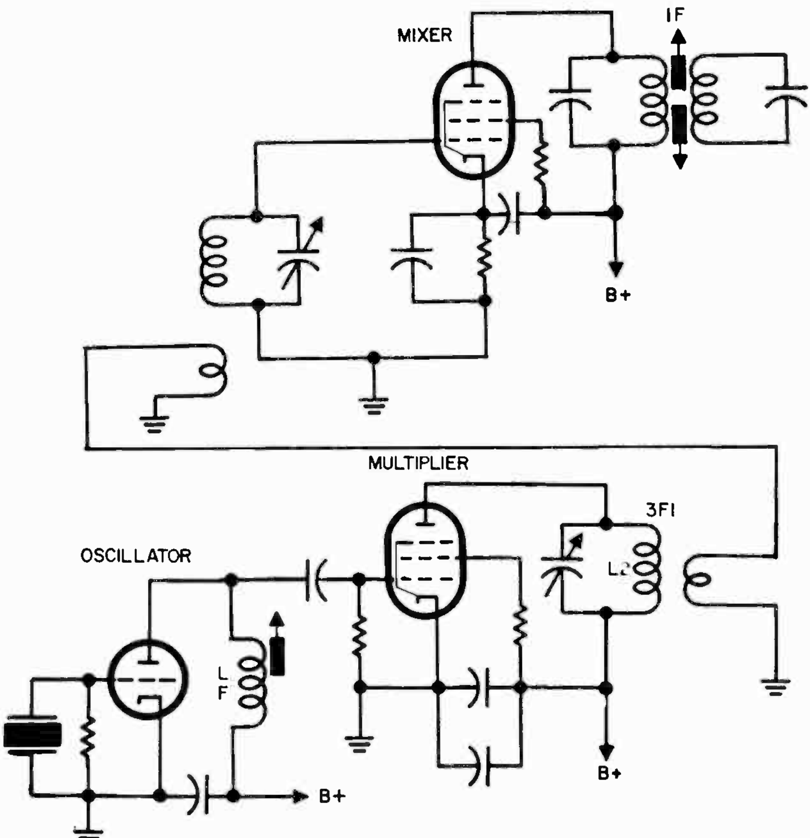


Fig. 1114. *Local oscillator, multiplier and mixer circuits. Only one multiplier is shown. Some receivers use several frequency multipliers.*

The output of the crystal oscillator is capacitively coupled into a frequency multiplier. The multiplier has no cathode bias and so we have a fairly strong current through the tube. The current is enough to put the tube into the curved part of its characteristic—or, to talk just a little more plainly, we deliberately encourage the tube to distort. Now you might think that this puts us in the same position as the bank manager, who opens the vaults, doors and windows—and then goes home.

We want the tube to distort, since the output will then contain

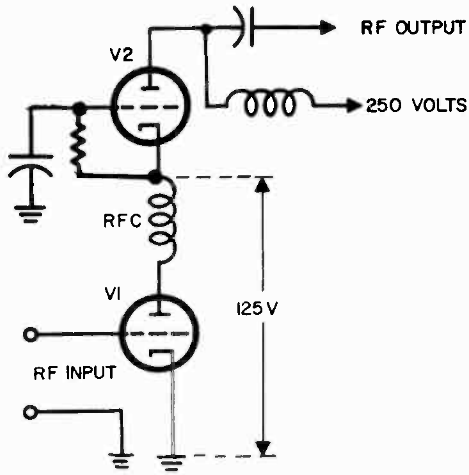


Fig. 1115. *Cascode rf amplifier circuit. The two tubes are connected in series.*

not only the fundamental but also harmonics. Having harmonics is like going to a big party. You pick what you want. In the case of Fig. 1114 we went the third harmonic. How do we know this? The tank coil is marked 3F1. This means that it is tuned to three times the fundamental frequency, F1. In some circuit diagrams you will see the actual frequency marked alongside the crystal and also the multiplier tank coils. Armed with this bit of information (supplied by the manufacturer) you will be able to decide whether you are working with a straight rf amplifier, a doubler or a tripler circuit.

To save space, the oscillator and multiplier tubes live under the same roof—that is, the tube can be a triode-pentode.

Cascode radio-frequency amplifier

Radio can be more full of surprises than a monkey out of its cage. You would expect pentodes to be used up in the front end of a mobile receiver . . . and for a few good reasons at that. They do not need to be neutralized (that is, we don't expect them to oscillate) and they supply a large amount of gain.

However, you will often find triodes since they produce much less noise than pentodes. What price do we pay? Triodes must be neutralized and their gain is much lower than pentodes.

Fig. 1115 shows two triodes in what we described earlier as a cascode circuit. Basically, it consists of a triode followed by a grounded-grid amplifier. Taken together, the two tubes supply at least as much gain as a single pentode and less noise. In the cascode of Fig. 1115, B plus is connected to the plate of V2 and indirectly the plate of V1. Note that the two tubes act as a voltage divider.

Since V1 is a straight rf amplifier, it needs to be neutralized. (See Fig. 1116.) This is done by means of a feedback coil L1. Capacitor C1 is included to keep B plus off the control grid. V2 does not need neutralization since the grounding of the control grid supplies a shield between the input and output circuits.

You may have trouble seeing V1 and V2 as a series setup. If (going back to Fig. 1115) we assume equal voltage drops across the two tubes, then the cathode of V2 will be at about 125 volts when the B-plus supply is 250 volts. Since the cathode of V2 is so much higher in voltage than its filament, we get an occasional breakdown.

Offhand you might think that the circuit of Fig. 1116 gets around this problem, but it doesn't. For the circuit of Fig. 1116 to work the B plus for V2 must be higher than that for V1. The cathode of V2 and the plate of V1 are almost at the same potential.

What's next?

Since we are now coming down the home stretch, you've probably realized just what our approach has been. Radio receivers used today are superheterodynes. If we start with this as our generalized heading, our next step would be to classify receivers as AM or FM. But where do we go from here?

Before we answer that one, suppose we ask a question. What is the difference between a low-cost ac–dc set and a communications receiver? Both are superhets and both can be AM. The same basic circuits are used in both.

The big difference is in the number of circuits and in special circuits. A low-cost home receiver might have just one if. A communications receiver could have three or four. A communications receiver could have special circuits such as noise limiters, delayed avc, tuning indicators, etc.

Thus, if you can repair a low-cost superhet, you should be able to (theoretically) repair any other superhet, provided you become acquainted with any new circuits involved.

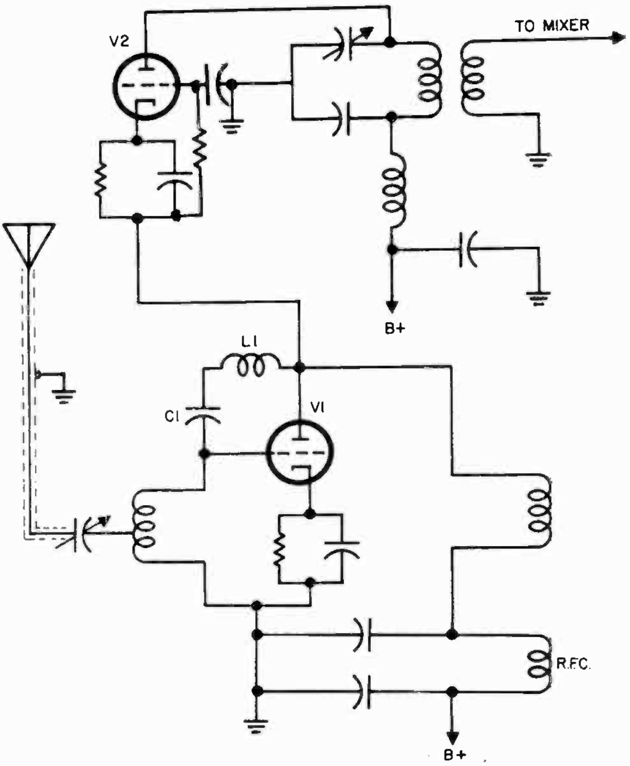


Fig. 1116. *The cascode circuit is a voltage divider.*

Does this mean that servicing is a hopeless case? Hardly! All you have to do is to consider the basic circuits of communications receivers, mobile receivers, marine receivers, etc., as just being specialized versions of the ac–dc set. All of the knowledge that you have about servicing can always be put to use.

Not all receivers come under our general heading of superhet AM or FM. We are going to cover these mavericks in the next chapter just so that your store of information about radio repair will be complete.

QUESTIONS

1. What are some of the operating frequencies used by mobile receivers?
2. What is a base station?
3. What is double conversion? Why is it used?
4. What is a frequency multiplier? Where is it used in a mobile receiver? Why is it used?
5. Why is the local oscillator crystal-controlled in some mobile receivers? How is the local oscillator frequency changed when crystal control is used?
6. Why is local oscillator frequency drift a serious problem in mobile sets?
7. A crystal-controlled local oscillator works at a fundamental frequency of 15 megacycles. It is followed by a doubler and two triplers. What frequency is fed into the mixer?
8. Why are squelch circuits used? Describe the operation of a squelch circuit.
9. What do qavc, a muting system and codan have in common?
10. Name four types of detector circuits used in receivers.
11. Why is distortion desirable in a multiplier circuit?
12. What is a cascode rf amplifier? How does it work?

CHAPTER 12 miscellaneous receivers

HOW MANY WAYS do you think there are of preparing an egg? Fried, boiled, sunny side up, omelette, poached? You could probably name at least half a dozen more. But would that be the end of the list? Not by any means. We must take into account those special cooks who can do things with eggs that we never thought of.

What has this to do with radio receivers? Well, if you can remember that one egg is pretty much like any other egg, and what can be done to one can be done to all of them, can you imagine what can be done with a whole collection of components?

Is it difficult?

When you take your first look at some odd receivers (odd because they may be new to you) you might be tempted to throw up your hands and say, "That's all, brother! I've had it." But how different are they? Just a radio, and usually a superheterodyne at that. And when you come right down to it, a superhet is just a mixer, a couple of if's, a detector and some audio. But (as with the egg) you can add circuits, change circuits, make parts do things you never expected.

The strange thing about all this is that you know how to service these sets. The tough part isn't the repair so much as being told just what is new or different. It's something like the difference between talking to an old friend and someone you have just met. It does take a little time for the strangeness to wear off.

Can we cover them all?

In this chapter we are going to tell you about different radio receivers, converters, preselectors, regenerative sets, etc. It would be impossible to cover them all, since, even as you read this, somewhere manufacturers are busy as little beavers making up new and unusual sets.

FM–AM portable

Do you remember all the different "crazes" we've had? For a while we had flag-pole sitters, marathon dancers, goldfish swallowers, mah jong players. After a while the novelty wears off and people get back to normal. However, once in a while some of these wild shenanigans turn out to be not so wild after all, and gradually make a comeback.

Take FM for example. In like a lion and out like a lamb. At one time, if you didn't have an FM receiver you were the next thing to being a social outcast. But then FM lost its popularity and FM sets became just another ornament. When it was "rediscovered" people began to realize that FM could supply some very good music that sounded sweeter and better than AM broadcasting.

Fig. 1201. *Outside view of the 12-transistor AM-FM portable.* (Sony)

If there is anything you can say for Americans as a group, you can say they always go "whole hog." If they like something, they really like it. And so, when FM made its comeback, it did so with a great big rush. We now have FM not only in the home, but in automobiles, and as portables. Take a look at Fig. 1201, a picture of a 12-transistor AM-FM portable receiver. Fig. 1202 is

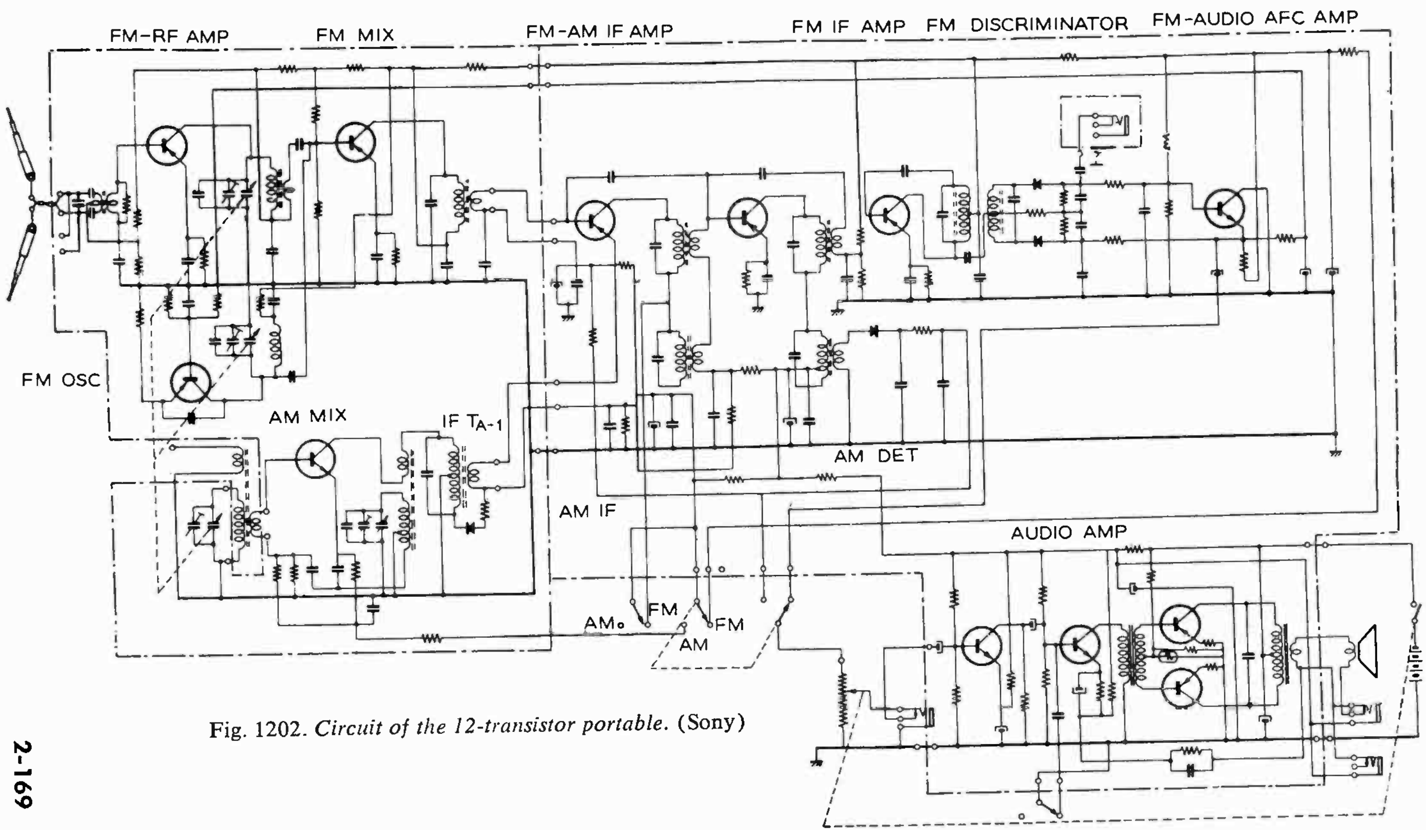


Fig. 1202. *Circuit of the 12-transistor portable.* (Sony)

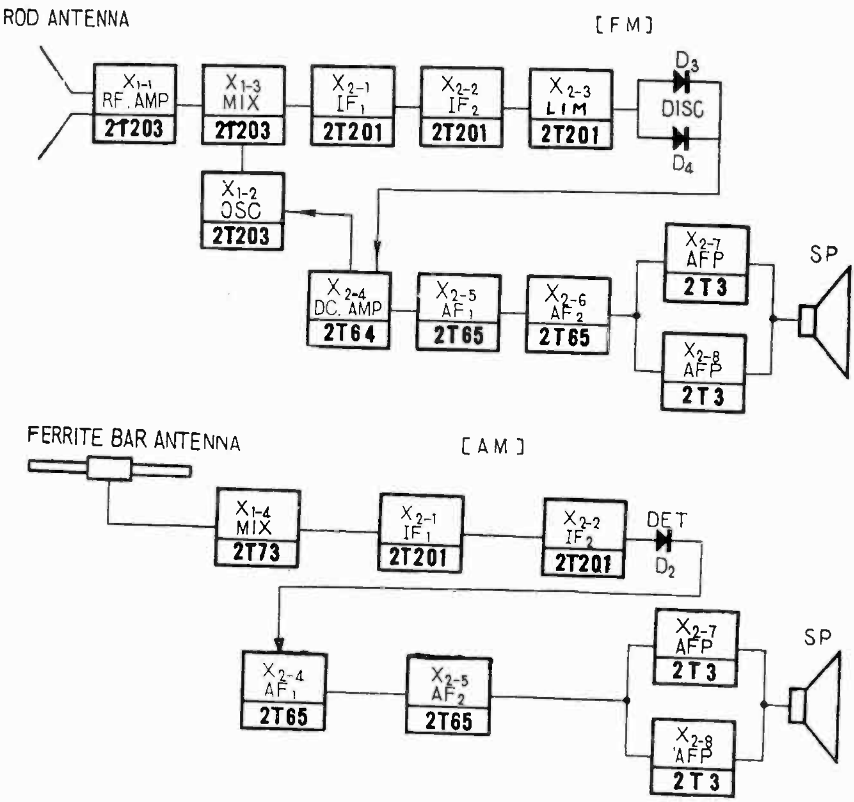


Fig. 1203. *This block diagram of the AM-FM transistor portable shows that more stages are used for FM broadcast reception (top) then are required for AM broadcast listening.* (Sony)

the circuit diagram. This portable, incidentally, can also be used as an AM–FM tuner.

A first look at Fig. 1202 might convince you that the circuit is complicated, but take a second look. As in most receivers that pick up more than one band, some of the components do double duty–that is, they work for both bands.

Let's take the FM section. It has a telescoping dipole antenna (mounted on the handle of the receiver). The signal passes through through an rf amplifier stage into a triode transistor mixer. The mixer receives the local oscillator voltage from another transistor.

Following the mixer we have three transistor if stages. The FM detector is a discriminator circuit with audio output taken off through a jack for a pair of earphones. There are several stages of audio amplification and then push-pull output.

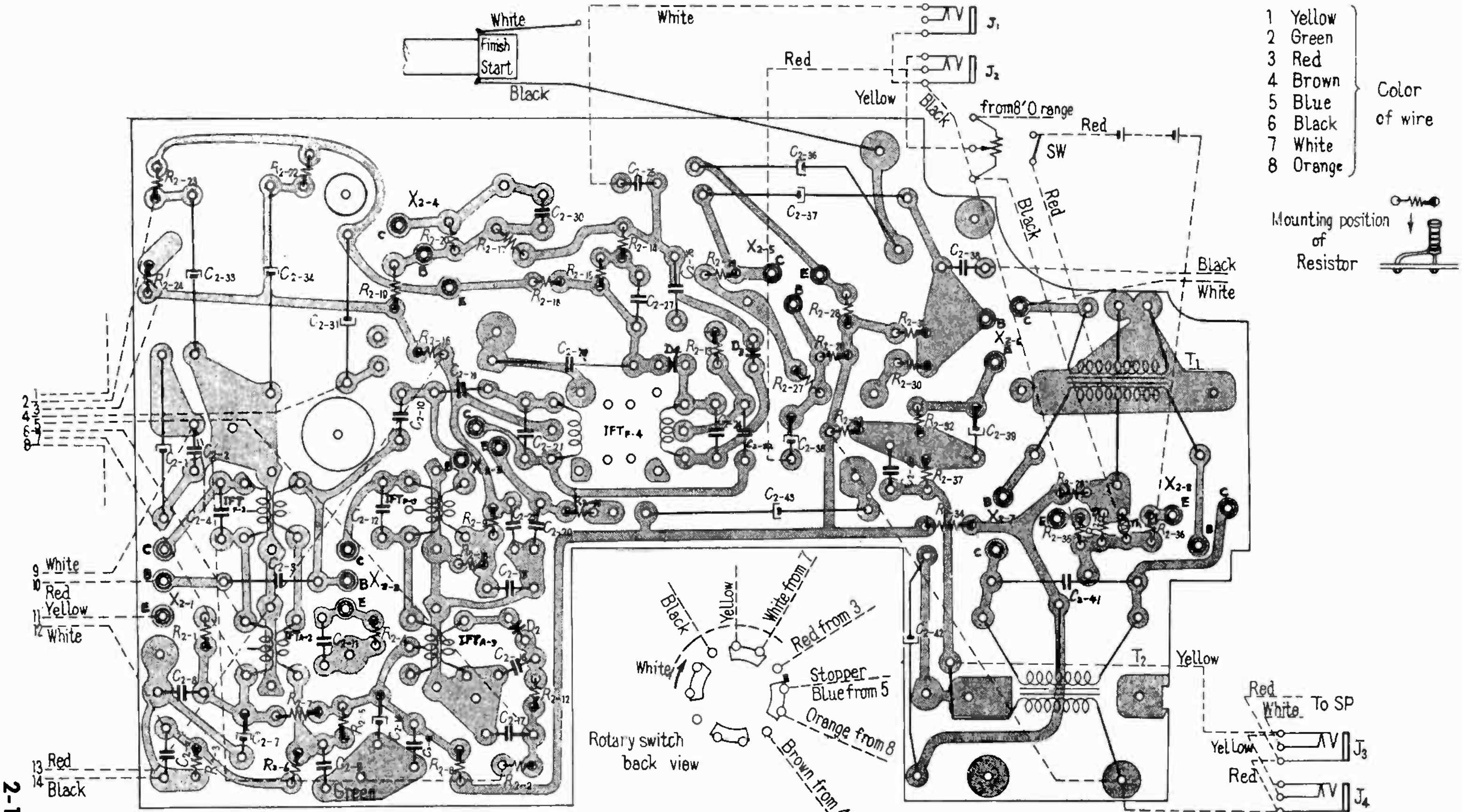


Fig. 1204. *The if and af sections of the 12-transistor receiver are mounted on a printed-circuit board.* (Sony)

The AM section is a little less elaborate. The signal is brought into an AM mixer. The same transistors that are used for the FM intermediate-frequency stages are also used for the AM intermediate frequency. The AM detector is a crystal diode. The audio output of the AM detector is fed to the same audio amplifier as the FM.

You can get a better idea of the circuit by following the block diagram shown in Fig. 1203.

On AM the receiver covers 535 to 1605 kc. For FM, the range is 86.5 to 108 mc. The if for the AM section is 455 kc. while it is 10.7 mc. for FM. For AM, the antenna is a built-in ferrite bar provided with a jack for an external antenna. For FM, a built-in balanced rod antenna is used. There are also terminals for using a balanced type external antenna (such as a dipole) having 75 to 400 ohms impedance. The entire set is powered by four size C flashlight batteries (total–6 volts).

Circuit details

Like most of the transistor sets we covered earlier, the circuit of Fig. 1202 uses almost all p-n-p transistors. Be careful, though. The AM mixer and some of the audio amplifiers are n-p-n's. While both types are used, the positive terminal of the battery is grounded.

There are two printed-circuit boards. One is for the if and af section (Fig. 1204), while the other is for the rf section (Fig. 1205). A large part of the copper foil material on these boards is at ground potential.

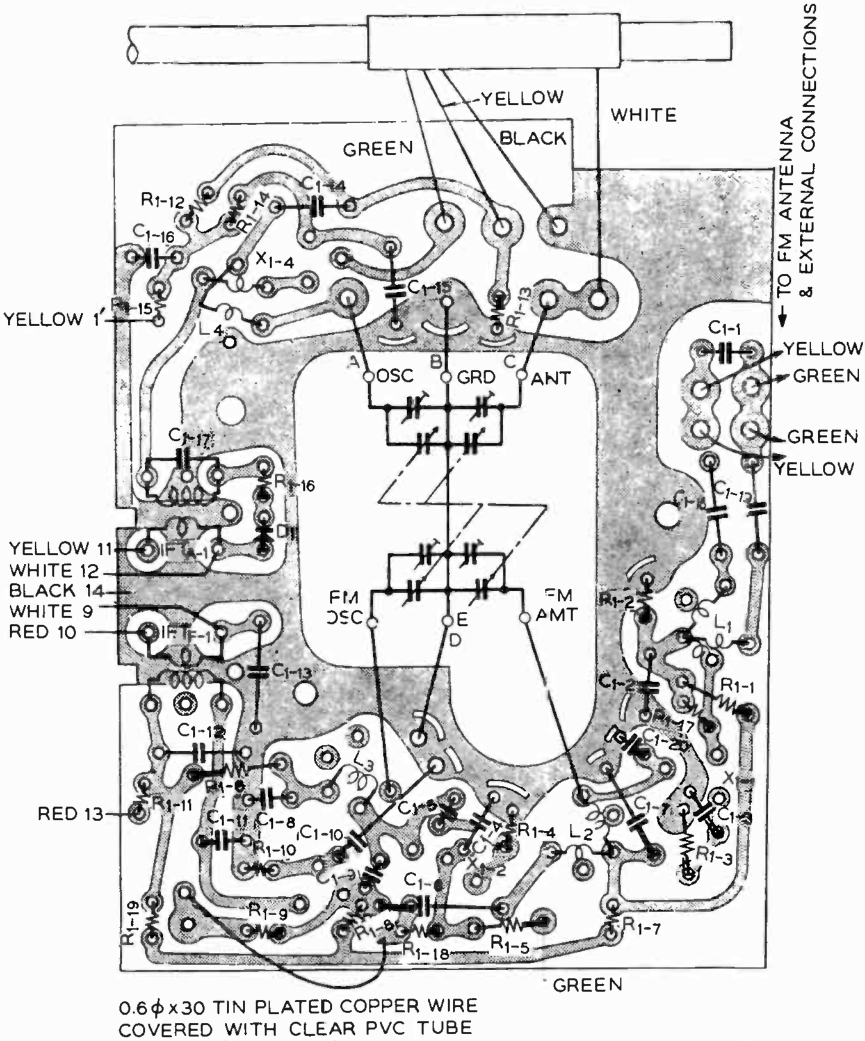
AM-FM switching

Most of the circuits are used for both AM and FM. Those that are not are switched on or off, depending on whether AM or FM is wanted. When the set is switched to FM, here are the changes that are made:

1. The converter circuit is switched to FM.
2. A limiter circuit is added to the if stage.
3. Afc current is fed to local oscillator X1-2 through dc amplifier X2-4. (Fig. 1203.)

The if stage

The if stage works as a grounded emitter circuit for FM and as a grounded-base circuit for AM. The purpose of the change is to prevent unstable operation due to excessive gain at 455 kc.



TOP HEIGHT OF COMPONENT FROM CIRCUIT BOARD SURFACE

$X_{1-1,2,3}$	MUST BE LESS THAN 17MM
$C_{1-2,4,6}$, $C_{1-7,8,10}$, $C_{1-18,19}$	MUST BE LESS THAN 11MM
$C_{1-5,9}$	MUST BE LESS THAN 5MM

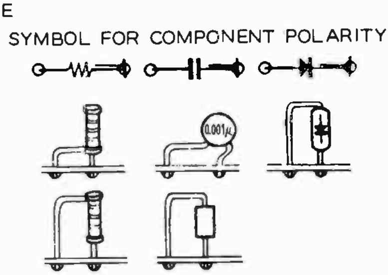


Fig. 1205. *Schematics that come with imported receivers include more information than we are used to seeing. Here component polarity is indicated. In compact units component size and height are important.* (Sony)

Afc operation

For portable FM radio, we need an afc circuit to minimize detuning due to "body effect" or variation of the local oscillator frequency because of the transistor's temperature characteristics.

Here is how the automatic frequency control circuit works: Let us say that the local oscillator shifts in frequency. A dc voltage is developed at the output of the FM discriminator. This voltage is applied to the base of X2-4, which works as a grounded collector dc amplifier. The output voltage, taken from the emitter of transistor X2-4 is sent along to the base of transistor X1-2, the local oscillator. On the way, the correction voltage is filtered by a resistor and capacitor.

The dc correction voltage changes the collector current of the local oscillator, at the same time changing the frequency of resonance of the oscillator tuned circuit. But what is this change? It

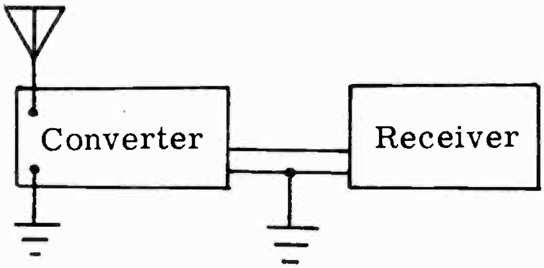


Fig. 1206. *The converter and the receiver, working together, form a double-conversion superheterodyne.*

is in the direction of correct local oscillator frequency. When this happens, the dc correction voltage disappears and will remain at zero as long as the local oscillator is on frequency.

A little earlier we mentioned "body effect." Sometimes known as "hand capacitance," it is simply the ability of the body to change the frequency of an oscillating circuit. To test it for yourself, bring your hand close to (but not touching) a tuned coil in the front end of a receiver and note how you can tune the set in and out just by moving your hand.

Because the action of afc is important and because you will run across afc in many well built FM receivers, let's review it on a step-by-step basis:

1. Local oscillator shifts.
2. The if frequency deviates from the center frequency.

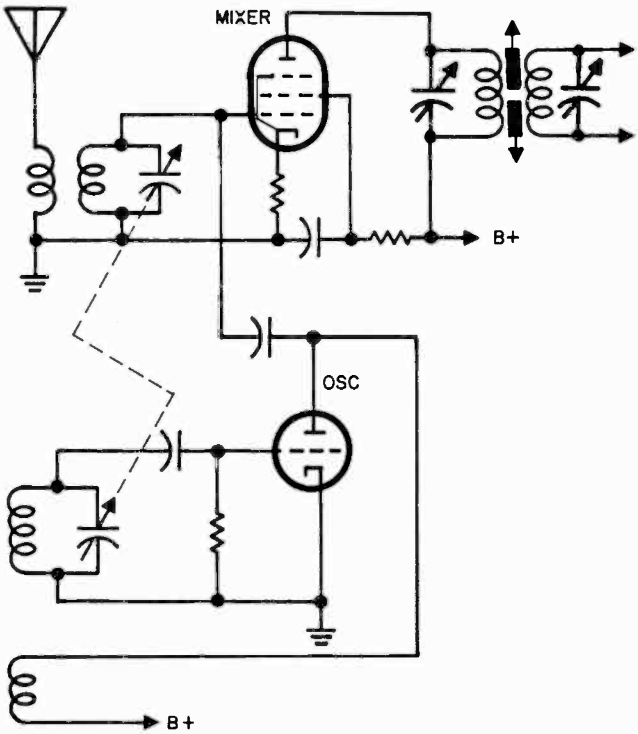


Fig. 1207. *Converter circuit. Some converters use an rf amplifier while others have crystal-controlled oscillators.*

3. A dc voltage appears across the discriminator output.
4. The dc voltage is amplified.
5. The dc voltage is fed back to the base of the local oscillator.
6. The dc voltage sent to the local oscillator changes its base bias.
7. This changes the collector current of the local oscillator.
8. The change of collector current modifies the frequency of the tuned circuit connected to the collector.
9. This change brings the local oscillator back to its original frequency.
10. As the local oscillator moves back to its original frequency, the if deviation becomes less and less, and the dc voltage across the discriminator reduces until it disappears.

Converters

We studied FM and AM tuners in Chapter 8. At that time we learned that a tuner was half a radio and that it included all circuits

You may be wondering why we don't run an agc lead from the receiver out to the converter, instead of using an rf gain control. There are several reasons for this. The first is that it is more convenient to have the minimum number of connections between the converter and the receiver. In Fig. 1208, the converter is self-powered—that is, it has its own battery.

There is another and more important reason. We don't know whether the communications receiver is a transistor or a tube type. And even if the communications set is a transistor type, its agc voltage may be of the wrong polarity for the type of transistors used in the converter.

The converter circuits we have covered are just a few of the many available types. Some use a single tube, while others have

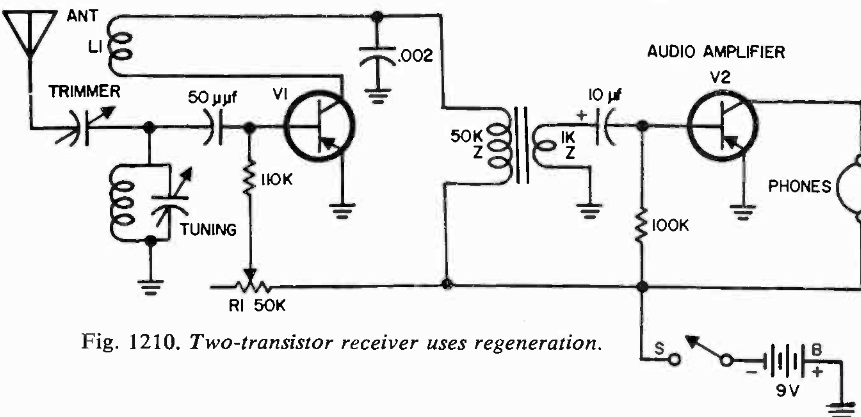


Fig. 1210. *Two-transistor receiver uses regeneration.*

three or four. Some cover a single band (such as the broadcast band) while other converters have elaborate switching systems to tune many different bands. Some have transistors. Others have tubes. Deluxe converters have an rf amplifier stage and may have one or two if stages before the output. But no matter how simple or complicated they may be, all they can be, basically, is a mixer circuit.

FM converters

As you know, the FM band (88 to 108 mc) is sandwiched between the lower and the higher TV channels. The sound part of a TV set is FM and so a converter can be used to pick up FM broadcast signals. A converter of this type is shown in Fig. 1209.

Note the switching arrangement in Fig. 1209. The television set can remain permanently attached to the converter. With the help of a switch, the television set can be connected directly to the antenna for TV reception. This same switch turns the converter battery supply off.

Regenerative receivers

Did you ever get stuck with a "dead" car battery? One way of getting into motion is to get a push but, if you're on the downgrade of a hill, so much the better.

In a radio receiver we can get some extra gain out of the set by taking part of the output and feeding it (in phase) back to the

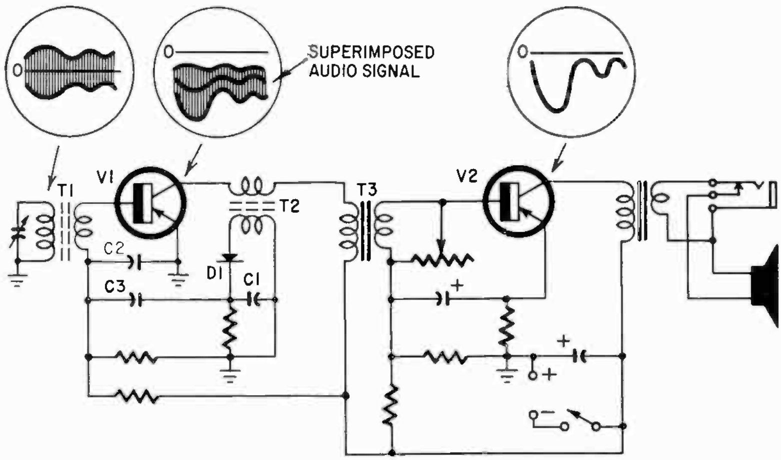


Fig. 1211. *Reflex receiver gets maximum effort out of transistors.*

input. As with our dead car on the hill, we take advantage of the "extra push" we can get from the output signal.

Fig. 1210 shows a two-transistor receiver using regeneration. The output signal is taken from the collector of V1 and fed back (through L1) to the base input. Since the fed-back signal is in phase with (in step with) the incoming signal, the signal is strengthened. The amount of feedback is controlled by R1. If feedback is permitted to become too strong, the first transistor V1, will oscillate.

You might think that no one would be interested in a two-transistor receiver, yet many of these low-priced "vest-pocket" types are being manufactured. They are usually about the same size as a pack of cigarettes. They can seldom receive more than a few stations.

V1, in Fig. 1210, is quite an important transistor. It acts as an rf amplifier and is also the detector. The output of the receiver is seldom strong enough to operate a speaker, although it will do so if the local station is strong enough and close enough.

The circuit of Fig. 1210 can be used to pick up CW signals. (This assumes, of course, that the tuning circuit covers bands on which CW is transmitted. Most of these two-transistor radios, though, are intended for the broadcast band.) With proper adjust-

Fig. 1212. *Front-view of a Citizens-band transceiver. Minimum number of controls gives this unit a clean look, makes it easy to operate.* (Allied Radio Corp.)

ment of R1, code signals will come through quite clearly. No extra bfo circuit is needed.

Troubles with regenerative receivers

It may be hard to believe (as the little boy said when he saw a giraffe for the first time), but there it is. You might think that nothing could go wrong with a two-transistor radio but they have their troubles just the same.

What can happen? The set may fail to regenerate. Most often the trouble is a weak battery, but it could also happen if the leads to coil L1 were transposed, if we had an open in R1 or in the primary of the audio transformer. You can "hear" if the set regenerates. Plug in the phones and advance R1. At some point you should hear a soft rushing noise. If you do, there is regeneration.

Test the audio section just as you would any audio amplifier. Follow the instructions given earlier on servicing audio stages.

Two-transistor reflex receiver

For economy, one transistor can be made to do the work of two. In the circuit of Fig. 1211, the first transistor, V1, amplifies the signal at the broadcast frequency and feeds it to a transformer-coupled diode detector, D1. From here, the signal voltage, now an audio frequency, is supplied to the ground end of the rf input tuned-circuit coupling winding. This is in series with the base of the first transistor.

Although this is a feedback circuit, neither regeneration (and possible oscillation) nor degeneration exists since the feedback would have to be at the broadcast frequency to have effect. Most or all of the rf is removed by C1 and C2.

The coupling winding in the base circuit of V1 has several effects. It acts as an rf choke as well as an inductively coupled trap, tuned to the broadcast frequency. Thus, there is little or no voltage able to support oscillation.

The audio signal voltage at the base of V1 is amplified again and coupled to the audio output stage through T3. The output stage needs no explanation since it is little different from that found in many other pocket portables.

For troubleshooting, an audio signal can be injected at the junction of D1, C1, C3. If audio is heard at this point but a station cannot be tuned in, it might indicate that the tuning circuit, T2 or D1 is defective.

Little or no servicing information is available for these receivers. Special parts such as T2, the volume control and the tuning capacitor, might be difficult or impossible to replace. V1 could probably be substituted by any appropriate transistor capable of 1.5-mc operation. D1 can be any diode small enough to fit, provided proper polarity is maintained.

For the most part these receivers are available for less than $10 and it is usually not worth while to repair them except for personal satisfaction.

Transceivers

Radio receivers and transmitters have so much in common that it isn't surprising to find them (sometimes) united in the bonds of holy matrimony. When this happens, what can we call the combination? Receiver? It's more than that! Transmitter? Still not good enough. The unit is really a transmitter-receiver—so we take the first part of transmitter and the last part of receiver, combine them, and come up with transceiver.

Fig. 1212 shows the front view of a transceiver. The tuning range is from 26.965 to 27.255 mc, covering all 23 channels of class-D Citizens-band.

This compact receiver can be put on top of a desk or fitted into a car or boat. The set has a single transmit-receive switch and a built-in ac power supply.

The more expensive models have better receivers. This usually is a high-sensitivity, double-conversion superheterodyne which can be tuned manually to cover all 23 channels. The receiver has a built-in noise limiter to reduce automobile ignition and other noises, and a squelch circuit to keep the receiver quiet until a signal is received. (In this book we are concerned with receivers. A license is required to repair any portion of the transmitter that will affect either its operating frequency or its power output. This license is acquired by examination. No examination is needed for the operator's license.)

Before we start talking about circuit details, look at the inside of the transceiver shown in Fig. 1213. Note the printed-circuit board mounted on a cutout in the metal chassis. In this trans-

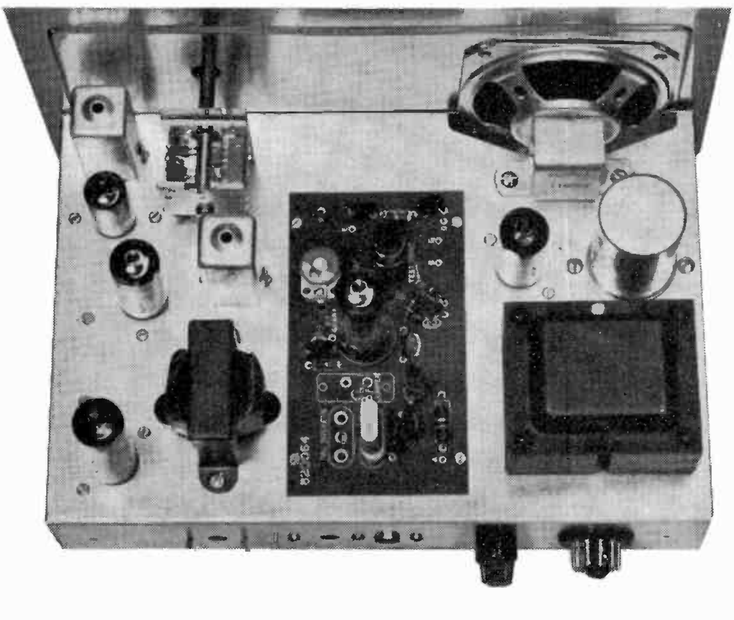


Fig. 1213. *Inside view of Citizens-band transceiver. The printed-circuit board is mounted on a chassis cutout.* (Allied Radio Corp.)

ceiver, both printed-circuit and point-to-point wiring are used. The printed-circuit board is held in place by four screws.

To learn more about transceivers, start by looking at Fig. 1214. Here we have the complete circuit diagram. The circuit shows that we have both a transmitter and a receiver. With the help of the transceiver we can talk to another unit or receive a signal from another transceiver. This function is selected by switch S1.

When the switch is put in the transmit position, the antenna is connected to the output of the transmitter, the microphone is connected to the audio amplifier while the speaker is disconnected from the circuit.

When S1 is put in the receive position, the antenna is connected to the receiver input and is tuned by L3 and C19. At the same time, the speaker is connected to the output of the audio amplifier and the microphone is disconnected from the circuit.

The receiver uses a superregenerative circuit. The first stage, V2, is an rf amplifier. Since superregenerative receivers can radiate, the rf amplifier helps isolate the superregenerative stage from the antenna to prevent radiation.

What is superregeneration?

The superregenerative circuit oscillates in two different ways. There is positive feedback from output to input–that is, from the plate to the grid circuit. This is regeneration and strengthens the 27-mc signal.

The more positive feedback we have, the more output we can get from the tube using the feedback. Like all good things, though, there is a limit. Use too much feedback and the tube starts to produce a sickening howl. To prevent this, we use an interruption voltage which turns the tube on and off very rapidly, preventing a buildup to a howling point.

The interruption voltage is called a quench voltage. The quench voltage usually has a frequency in the ultrasonic range – that is, somewhere above 30 kc.

Why the howling?

Regenerative receivers use a grid leak and a grid capacitor to supply bias to the regenerative detector tube grid. As we begin to use more and more feedback, the grid capacitor begins to discharge through the grid leak more and more slowly. Regeneration doesn't give the grid capacitor a chance to discharge and charge

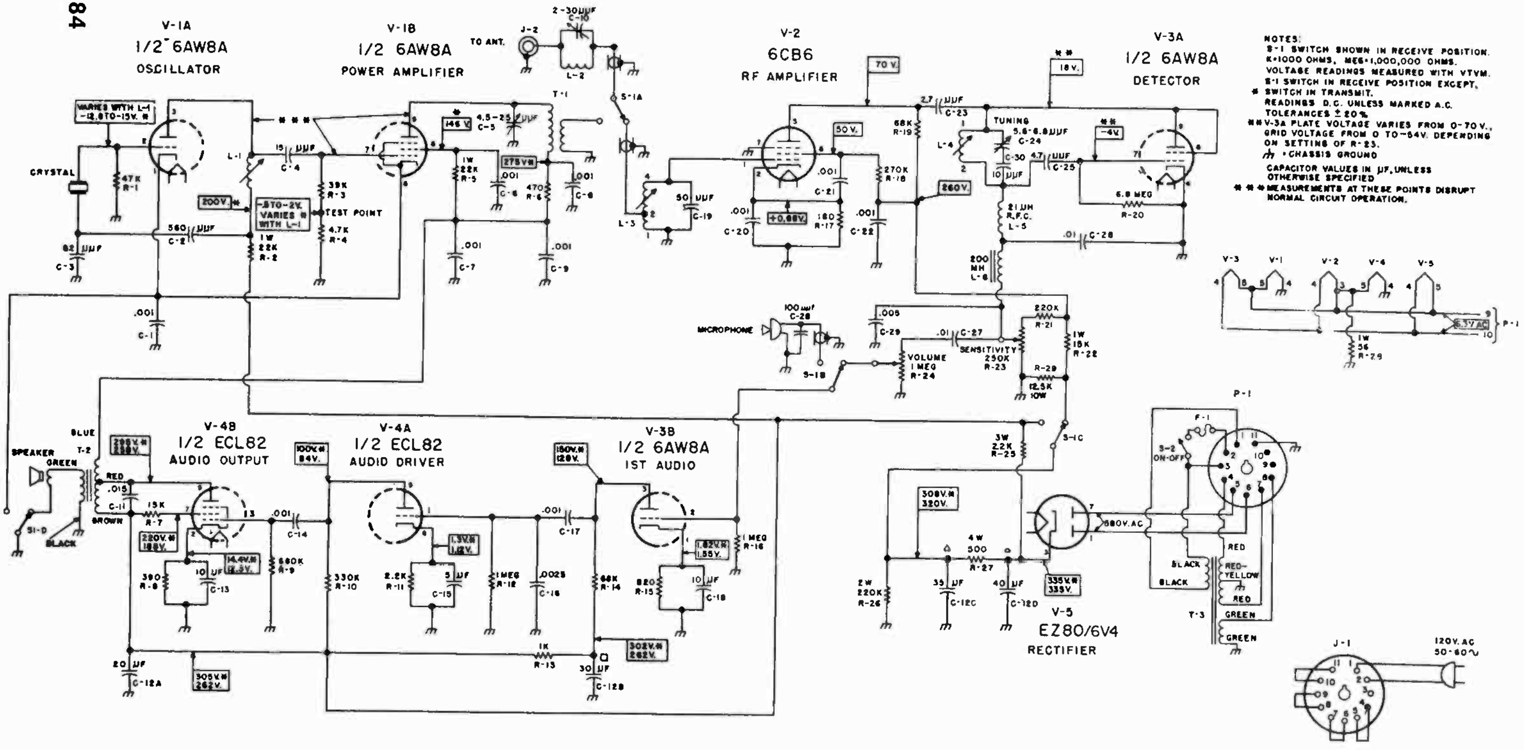


Fig. 1214. *Complete circuit of the transceiver.* (Allied Radio Corp.)

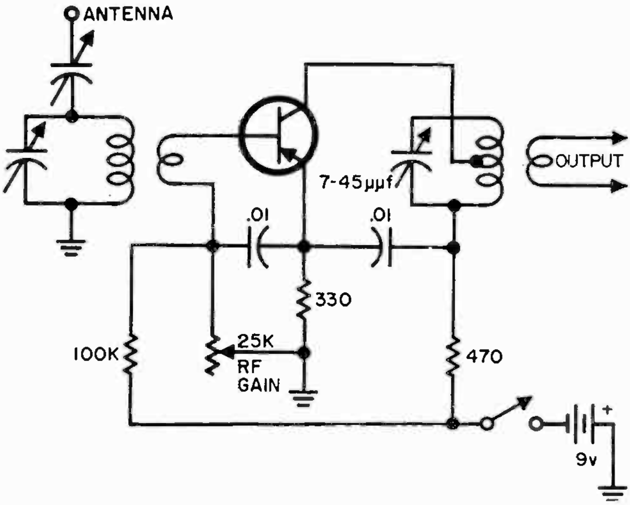


Fig. 1215. *Preselector circuit is a tuned radio-frequency amplifier.*

again at a very rapid rate. The effect is just as though we were turning the regenerative detector on and off at an audio rate. When we use a quench circuit, though, the grid capacitor (C25 in Fig. 1214) is forced to charge and discharge much faster – so rapidly that it proceeds at a ultrasonic rate. In Fig. 1214 the grid leak is R20.

Detection

Detector V3A is operated as a triode. When the signal is negative, the detector tube is cut off. Current flows through the detector tube when the signal becomes positive. Since the signal is neatly sliced in half, we get detection. The rectified signal appears in the grid-cathode circuit. Radio-frequency choke (rfc) L5 holds back the rf component of the detected signal, but has much less opposition for audio. Any rf that does get through is bypassed to ground by C26, a .01-μf capacitor. The audio signal is developed across the volume control and from there moves into the grid of the first audio amplifier tube.

Preselectors

Not all sets have as much rf gain as they should have.

For sets that need just a little more rf boost you can do one of two things (or both). A better outside antenna is a help. Often, though, this isn't possible. Another solution is to use a preselector. What is a preselector? It is just a tuned stage of radio-frequency amplification, as shown in Fig. 1215.

The preselector is usually a compact little unit and is self-powered. Some have a ferrite-loop antenna with a terminal for

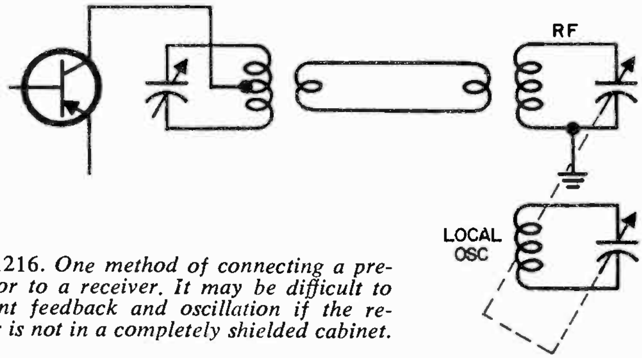


Fig. 1216. *One method of connecting a preselector to a receiver. It may be difficult to prevent feedback and oscillation if the receiver is not in a completely shielded cabinet.*

making connection to an outside antenna. Since the preselector uses a transistor, no warmup time is needed.

It does have one big disadvantage. It needs to be tuned every time the receiver itself is tuned. It all depends on the particular unit. Some have fairly broad tuning and so you will get some gain regardless of the position of the tuning capacitor. Other preselectors are selective, so they require more precise tuning.

The preselector in Fig. 1215 has an rf gain control. Generally, once this has been set, it requires no further attention. As the battery gets a little weaker, the gain control will need to be turned up a little more.

Connecting the preselector

If the radio receiver has an antenna-ground terminal board, just connect the secondary leads of the preselector output transformer to them. Most sets do not have such a terminal board, however, so you will need to make some changes.

One way of making the connection is shown in Fig. 1216. Another way is to connect the output of the preselector to a pair of capacitors. The exact value isn't critical. One capacitor should connect to the stator of the rf tuning capacitor or to the top of the rf coil—which ever connection is easier. The other lead should be attached to the ground bus.

Boosters

When used with a television receiver, the preselector is often called a *booster*. This design is usually different in that a sharply tuned circuit is not used. The tuned circuit may be so broad in response that it is called a bandpass filter.

In some locations, it is necessary to increase the signal to an FM tuner. In many instances, it is quite practical to utilize a TV booster, since the 88- to 108-mc frequency spectrum is higher than channel 6 and lower than channel 7. If this is done, make sure the booster will cover the FM broadcast frequencies. Some boosters are broadly tuned for channels 2 to 6, and for channels 7 to 13. Selection is made by a switch which gives choice of LO or HI band operation. Here, bandpass filters are used. Some boosters may have traps or band-rejection filters to reduce the amplification of FM or communications frequencies that might interfere with the TV picture quality. Such a booster would not give any advantage to an FM or communications receiver.

The end of the road

For quite a while radio receiver repair has been pushed into the background by its more glamorous relative—television. Television, though (as people are beginning to learn), requires full attention. Either you watch it or you don't. And if you don't, you might just as well turn it off.

With radio, though, you can do a dozen different things. You can listen to news, weather reports, get background music and still not be taken away from whatever else you might want to do.

Radio receivers are now moving in a number of directions—all at once. Radio sets are becoming smaller, so they can be carried in pockets right along with keys, billfolds, papers and other items. In the home, radio sets are being housed in large, fine pieces of furniture. In autos, boats, trains—wherever you have a vehicle that moves—you will find a radio.

Radio is being used for more than just entertainment. Its value as an aid in communications is growing more and more.

Receiver servicing is also growing. We hope you will let this section of your repair business grow with it.

QUESTIONS

1. What is the purpose of afc in portable FM receivers?
2. What is meant by correction voltage? Body effect?
3. What is the purpose of a converter attached as a separate unit to a receiver?
4. Why is regeneration used in some receivers?
5. How do you know when regeneration is working? If regeneration is inoperative, what would you do to repair the receiver?
6. From a servicing viewpoint, what are some of the disadvantages of reflex receivers?
7. What is a transceiver?
8. What is superregeneration? Why are rf amplifiers often used with superregenerative receivers?
9. What is a quench voltage? Why is it used? What is a typical operating frequency?
10. Describe method of connecting a preselector to a receiver.
11. What are boosters? How do they differ from preselectors? Can boosters always be used with radio receivers?
12. Describe the operation of afc in a transistor portable.

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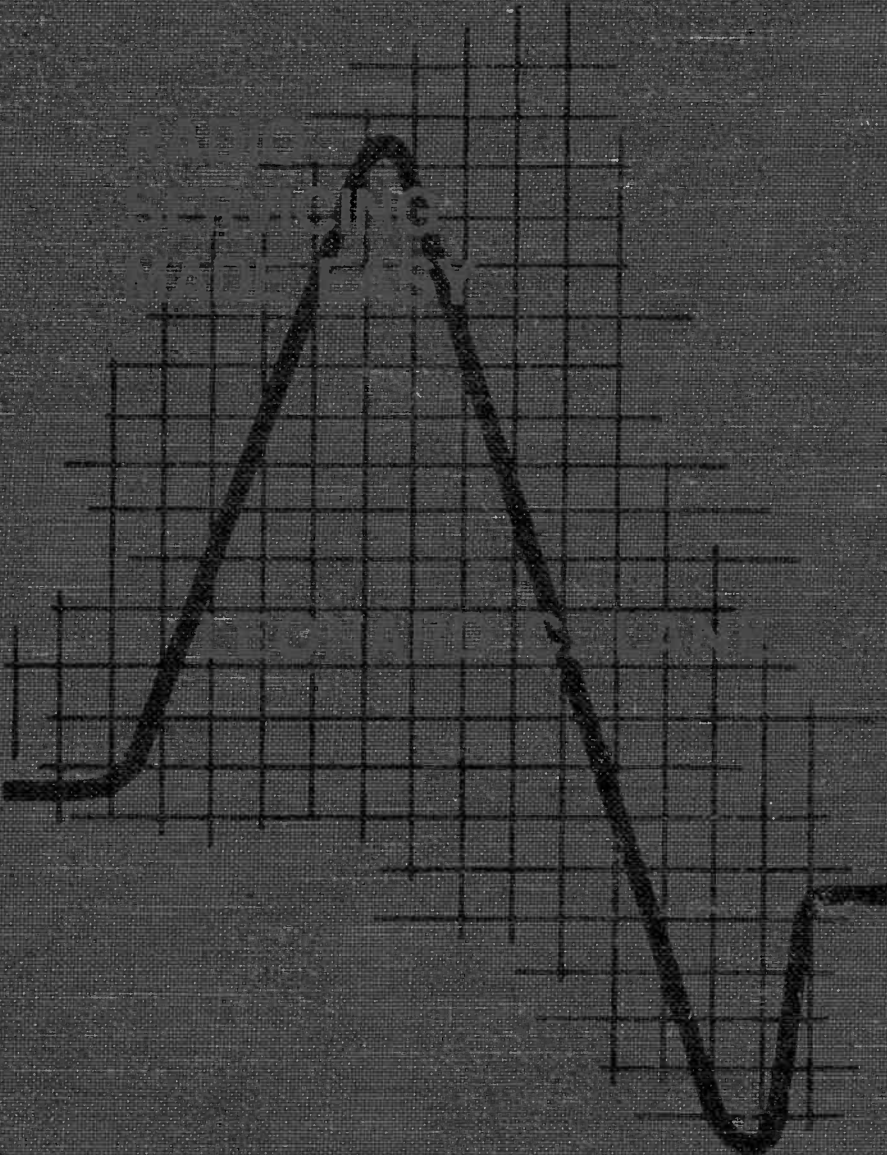
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