INSTRUCTIONS FOR PERFORMING RADIO EXPERIMENTS 51 TO 60

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NATIONAL RADIO INSTITUTE
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PIONEER HOME STUDY RADIO SCHOOL

A COURSE IN PRACTICAL DEMONSTRATIONS OF RADIO FUNDAMENTALS

NATIONAL RADIO INSTITUTE

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A LESSON TEXT OF THE N. R. I. COURSE
WHICH TRAINS YOU TO BECOME A
RADIOTRICIAN & TELETRICIAN
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INTRODUCTION

WITH experimental work on a.f. and r.f. oscillators completed, you are now ready to demonstrate how the a.f. signal can be separated from its r.f. carrier by a detector circuit.

With the conventional amplitude-modulated r.f. signal, detection is usually accomplished by rectifying the modulated r.f. signal, then filtering out the r.f. components. The peaks of the rectified signal vary in amplitude in accordance with the audio signal. If this rectified signal is allowed to flow through a resistor which is shunted by a condenser of the proper size, the d.c. voltage developed across the resistor will follow the peaks of the rectified r.f., and the resulting variations in this d.c. voltage form the a.f. signal. The shunt condenser by-passes the r.f. voltage components, and the d.c. voltage across the resistor may be eliminated by a blocking condenser in the output circuit, so that the detector feeds only the desired a.f. voltage to the next stage.

The three detector circuits which are most commonly used for demodulating an amplitude-modulated r.f. signal are:

1. *The diode detector,* a circuit in which a diode tube and resistor are usually connected in series with the modulated r.f. signal source in such a way that only one alternation of each signal cycle will send current through the diode detector circuit. This rectified current flow develops across the resistor a voltage from which the desired a.f. voltage can be obtained.

2. *The C bias detector,* also known as the plate bend detector; this uses the sharp plate current cut-off characteristic of a vacuum tube to provide both r.f. amplification and rectification of the modulated r.f. signal. Only positive alternations of the modulated r.f. signal can swing sufficiently positive from the cut-off point on the characteristic curve to give plate current flow through the plate load.

3. *The grid leak-condenser detector,* which is actually a diode detector and an a.f. amplifier stage combined in one vacuum tube circuit.

Amplitude-Modulated Detector Experiments. You will set up each of these three common types of detector circuits, using for your signal source in each case the plate-modulated signal generator which you assembled in the previous experiment. The r.f. output of this signal generator is less than 2 volts, which is somewhat low for satisfactory detection in most cases, and consequently you will use a stage of r.f. amplification in between the signal generator and the detector to build up the r.f. voltage.

While working with detector circuits, you will demonstrate how the a.f. output can be varied, as is necessary when a volume control is required. You will make experiments which reveal the characteristics of each type of detector, and will show how some detectors reduce the gain of the preceding r.f. stage because of their loading effects.

Superheterodyne Experiments. After completing your work with detector circuits, you will perform a number of important experiments with the widely used superheterodyne circuit. As you know, the basic principle of this circuit is conversion of the incoming r.f. carrier frequency to a fixed lower carrier frequency known as the intermediate frequency, with the greatest amplification being attained at this intermediate frequency. The frequency converter stage in a superheterodyne receiver serves to combine the incoming signal with a locally generated r.f. signal, then mixes the combined signals to give the desired i.f. frequency.

You will set up a frequency converter consisting of a mixer-first detector stage and a local r.f. oscillator stage, so as to demonstrate for yourself this important principle of frequency conversion. You will make measurements to show that a frequency converter stage can also provide gain.

Having produced an i.f. signal with the frequency converter stage, you will use the N.R.I. Tester as a conventional C bias detector to separate the audio modulation from the i.f. carrier, so that you can listen to the audio signal.

The i.f. transformer plays an important part in a superheterodyne receiver. You will demonstrate the importance of tuning this i.f. transformer to resonance, show that loading of the i.f. transformer reduces gain, and show that varying the mutual coupling in an i.f. transformer affects both the gain and the selectivity.

Having constructed the basic stages of a superheterodyne receiver, you will introduce various common types of interference into your circuit.

Most of the receivers in use today employ automatic volume control to maintain the loudspeaker volume essentially constant as signals of different strengths are tuned in. Automatic volume control also serves to minimize the effects of fading, in which case the time constant of the a.v.c. circuit is important. You will demonstrate this for yourself in one experiment.

Frequency Modulation. Although broadcast stations and the majority of short-wave stations today employ conventional amplitude modulation (a.m.) of the carrier signal, frequency modulation (f.m.) is in use for communication purposes as well as for radio broadcasting.

To secure experience with f.m., you will change over the amplitude-modulated signal generator which you built in Experiment 50 so that it will produce a frequency-modulated r.f. signal. To accomplish this, you will use a vacuum tube circuit in such a manner that its inductance varies in accordance with the audio signal, just as is done in commercial f.m. apparatus and in automatic frequency control circuits. This tube, known as the *oscillator control tube,* will shunt the tank circuit of the r.f. oscillator, with the result that the varying inductance will cause the frequency of the r.f. oscillator to vary in accordance with the audio signal, as is required for frequency modulation.

You will make tests which prove that a conventional a.m. type of detector will not be affected by this f.m. signal, and you will then build and use one type of the special discriminator circuit required for detection of f.m. signals. This experiment gives you a basic understanding of both the transmission and the reception of f.m. signals.

Superheterodyne Receiver. Finally, you will build a complete superheterodyne receiver, including a mixer-first detector, a local oscillator, an i.f. amplifier, a second detector, and an audio amplifier. Using the N.R.I. Tester as a servicing instrument, you will make continuity and voltage tests on it just as you would for an actual service job, then align your superheterodyne receiver to the frequency of a nearby broadcast station.

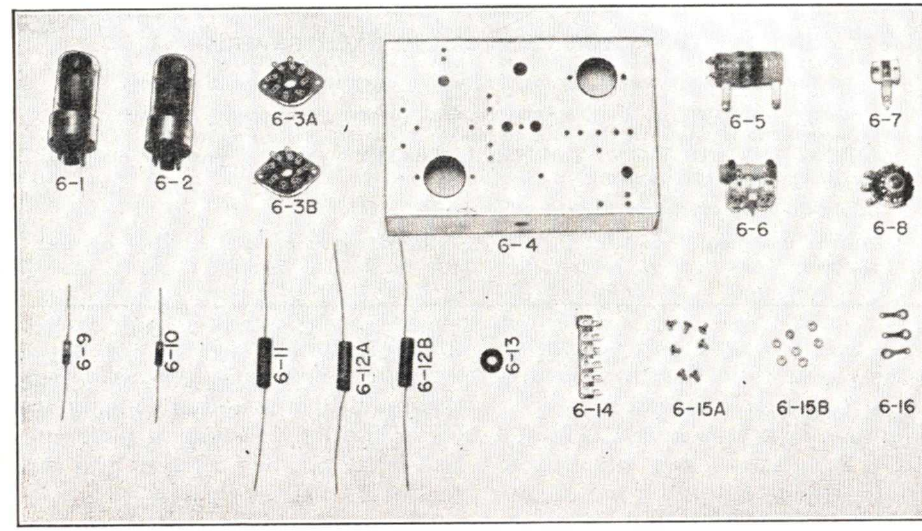


FIG. 1. The parts included in Radio Kit 6RK are pictured above, and identified in the list below. Some resistors may have a better tolerance (lower percentage tolerance), and some condensers may have a higher (better) voltage rating than that indicated here.

Part No.	*Description*
6-1	**One type 6SJ7GT sharp cut-off pentode vacuum tube.**
6-2	**One type 6SK7GT remote cut-off pentode vacuum tube.**
6-3A	**One octal-type socket with 8 lugs.**
6-3B	**One octal-type socket with 8 lugs.**
6-4	**One cadmium-plated steel chassis.**
6-5	**One superheterodyne circuit oscillator coil.**
6-6	**One double-tuned i.f. transformer (456 kc.) with variable coupling.**
6-7	**One 370-mmfd. mica trimmer condenser.**
6-8	**One 250,000-ohm potentiometer with a.c. power switch.**
6-9	**One 10,000-ohm, ½-watt resistor with 10% tolerance (color-coded brown, black, orange, silver)**
6-10	**One 2-megohm, ½-watt resistor with 10% tolerance (color-coded red, black, green, silver).**
6-11	**One .0005-mfd., 200-volt tubular paper condenser.**
6-12A	**One .01-mfd., 400-volt tubular paper condenser.**
6-12B	**One .01-mfd., 400-volt tubular paper condenser.**
6-13	**One rubber grommet.**
6-14	**One 6-lug terminal strip, with four of the lugs insulated.**
6-15A	**Seven ¼-inch long, 6-32 cadmium-plated binder-head machine screws.**
6-15B	**Seven cadmium-plated hexagonal nuts for 6-32 screws.**
6-16	**Three 13/16-inch long tinned soldering lugs.**

Contents of Radio Kit 6RK

The parts included in your Radio Kit 6RK are illustrated in Fig. *1* and listed in the caption underneath. Check off on this list the parts which you have received, to be sure you have all of them. You will also need the N.R.I. Tester, the power pack, and the amplitude-modulated r.f. signal generator which you assembled in previous experiments, along with all parts which were supplied in earlier kits.

IMPORTANT: If any part in your Radio Kit 6RK is obviously defective

INSTRUCTIONS FOR PERFORMING EACH EXPERIMENT

1. **Read the entire experiment, giving particular attention to the discussion.**
2. **Perform each step of the experiment and record your results. Whenever a measurement is specified, be sure to make it exactly according to the "OPERATING INSTRUCTIONS FOR N.R.I. TESTER" given *in previous manuals* for that type of measurement.**
3. **Study the discussion and analyze your results.**
4. **Answer the report statement for the experiment. It is on the last page of the manual.**

or has been damaged during shipment, please return it to the Institute *immediately* for replacement.

Tubes. The types 6SJ7GT and 6SK7GT vacuum tubes supplied to you in Radio Kit 6RK are single-ended r.f. pentodes. Both have the same prong connections, as shown in Fig. *2*, but their electrical characteristics are different; the 6SJ7GT has a

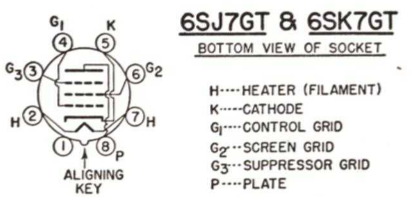


FIG. 2. Socket connections for the types 6SJ7GT and 6SK7GT tubes which are supplied to you in Radio Kit 6RK, as they appear if looking at the bottom of the socket when the chassis is upside-down. This diagram also applies to the prongs on the tube base itself if you hold the tube upside-down and look down upon the prongs. Note that terminal *1* is adjacent to the aligning key in a clockwise direction; this rule applies to all octal sockets.

sharp cut-off characteristic, while the 6SK7GT has a remote cut-off characteristic (variable mu).

These tubes have a rated filament voltage value of 6.3 volts, which means that they can be used with a filament supply voltage anywhere between 5.5 volts and 7.0 volts. The filament current drawn at the rated filament voltage is .3 ampere.

With a d.c. plate voltage of 250 volts, a screen grid voltage of 100 volts and a negative C bias voltage of 3 volts, the type 6SJ7GT tube will draw a plate current of 3 ma. and a screen grid current of .8 ma. With these same d.c. operating voltages, the 6SK7GT tube will draw a plate current of 9.2 ma. and a screen grid current of 2.4 ma.

Of course, it is not necessary to operate these tubes at the d.c. voltage values mentioned. The plate and screen grid current values will change correspondingly when the electrode voltages are changed.

EXPERIMENT 51

Purpose: **To show that a C bias detector will demodulate an amplitude-modulated r.f. signal and at the same time contribute r.f. gain; to show that a C bias detector circuit detunes the output resonant circuit of the preceding r.f. stage and, under certain conditions, also loads the preceding stage.**

Preliminary Discussion. The schematic diagram of the r.f. amplifier and C bias detector stages which you set up for this experiment is shown in Fig. *3*. Note that the type 6SK7GT tube is used in the r.f. stage, with signals being fed into the grid circuit of this stage by the amplitude-modulated r.f. signal generator assembled in the previous experiment. The antenna coil supplied in Radio Kit 5RK is used as a tuned secondary r.f. transformer for coupling the r.f. stage to the input of the type 6SJ7GT tube in the detector stage. The audio output voltage of the detector appears

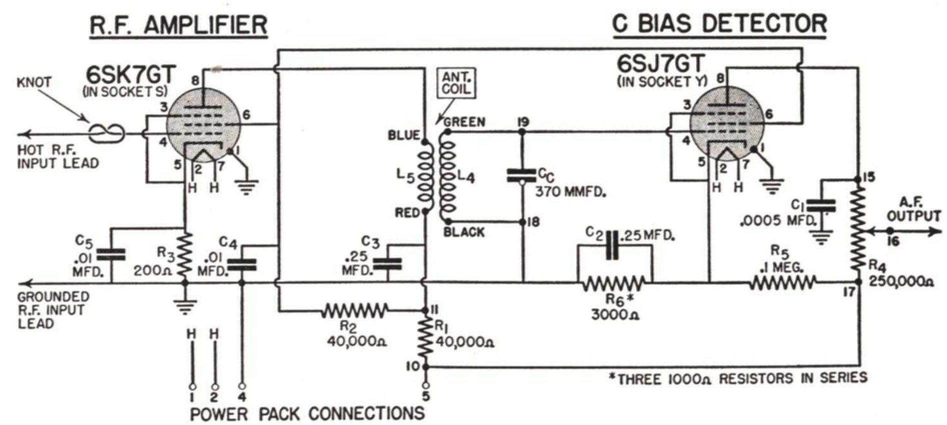


FIG. 3. Schematic circuit diagram for the r.f. amplifier and C bias detector stages which you set up for Experiment 51. Filament connections have been left incomplete, in accordance with standard practice for schematic circuit diagrams; the notations *HH* mean that the filaments of the two tubes are to be connected in parallel to output terminals *1* and *2* of the power pack.

across 250,000-ohm potentiometer R_4, and any desired portion of the total a.f. voltage may be obtained by adjusting the position of the movable contact on the potentiometer. All d.c. electrode supply voltages are obtained from your power pack.

You will assemble this circuit according to the detailed step-by-step instructions which will now be given, using the chassis layout diagram in Fig. *4* and the semi-pictorial wiring diagram in Fig. *5* as your guides.

Step 1. To mount on the chassis supplied to you in this kit the parts needed for the r.f. amplifier and C bias detector stages, carry out the following instructions carefully.

a. Secure the chassis supplied to you in Radio Kit 6RK, place it upside down in front of you in exactly the position shown in Fig. *4*, then locate holes *a, b, c, d, e, f, g, h, i, j* and *k* on the chassis and identify each with metal-marking crayon exactly as indicated in Fig. *4*. This chassis will be called the *experimental chassis*, to distinguish it from the signal generator chassis.

If you desire, you can identify these eleven holes on top of the chassis with metal-marking crayon in the same manner, being sure that your marking above the chassis for each hole is the same as the marking underneath the chassis.

Do not place any other markings on the chassis at the present time. The remaining holes are used chiefly for mounting parts, and Fig. *4* is an adequate guide for locating these holes.

b. Insert the rubber grommet in hole *k* on the side of the chassis.

c. Insert one of the octal-type tube sockets in hole *y* from the bottom of the chassis, in such a way that the aligning slot is nearest to hole *ll*. Fas-

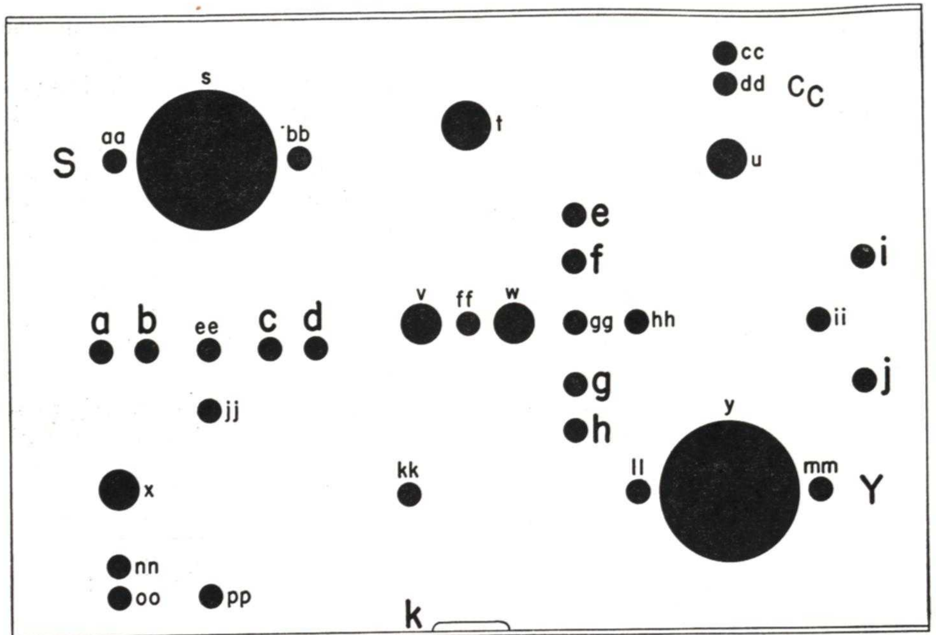


FIG. 4. *Bottom* view of the experimental chassis supplied to you in Radio Kit 6RK, with all holes identified. Holes *a, b, c, d, e, f, g, h, i, j* and *k* can be identified on both sides of your own chassis with metal-marking crayon exactly as indicated here, but do not make any other marks on your chassis at this time.

ten this socket to the chassis only at hole *mm* now, using a binder-head machine screw and nut.

d. Mount the 6-lug terminal strip over holes *kk* and *ll* underneath the chassis, as indicated in Fig. *5*. Bolt the strip to the chassis with two binder-head machine screws and nuts. This will automatically complete the mounting of the socket.

e. Mount the other octal-type tube socket in hole *s*, with the aligning slot toward hole *aa*.

f. Take the 250,000-ohm potentiometer (Part *6-8*) and examine it to see if there is a small metal locking tab projecting on the shaft side of the unit, as indicated in Fig. *5A*. If so, bend the tab inward. (Some parts do not have this tab.) Now remove the nut from the threaded shaft, insert the potentiometer shaft in hole *t* from underneath in such a way that the lugs are pointing toward holes *v, ff* and *w*, then replace and tighten the nut to complete the mounting of the potentiometer. Note: All three terminals of this 250,000-ohm potentiometer are insulated from the potentiometer shaft, and hence are insulated from the chassis also.

g. Mount a 370-mmfd. trimmer condenser underneath the chassis in holes *cc, dd* and *u*.

h. Mount the antenna coil (supplied in Radio Kit 5RK) on top of the chassis in holes *hh* and *ii*, with its terminal lugs near holes *e, f, g* and *h*.

i. Identify the six lugs on the terminal strip with the numbers *9, 10, 11, 12, 13* and *14* marked on the chassis near the respective lugs with metal-marking crayon as shown in Fig. *5*, just as you did on the chassis used in the previous group of ten experiments.

j. Identify the potentiometer terminals with the numbers *15, 16* and *17* placed on the chassis near the respective terminals in the manner shown in Fig. *5*.

k. Identify the trimmer condenser with the marking C_C placed on the chassis near the condenser both above and below the chassis, then identify the terminals with the numbers *18* and *19*, as indicated in Fig. *5*.

l. Identify the tube socket which is mounted in hole *s* with a large letter *S* placed on the chassis near this socket, both on top of and underneath the chassis, as indicated in Fig. *5*, then place a large letter *Y* near the other tube socket in this same manner. This will enable you to distinguish between the two identical sockets.

If you are now familiar with the numbering of terminals on a standard octal-type tube socket, there is no need to mark the socket terminal numbers on the chassis. Since these terminal numbers are embossed on the socket itself in small letters, you can always verify your identification of a terminal by examining the socket carefully. There is no objection to placing additional numbering on the chassis for the socket terminals if you prefer, however.

Step 2. Complete the wiring of your r.f. amplifier stage and C bias detector stage in the following manner, making temporary hook or lap joints in every case. Use your own judgment as to the best time for soldering

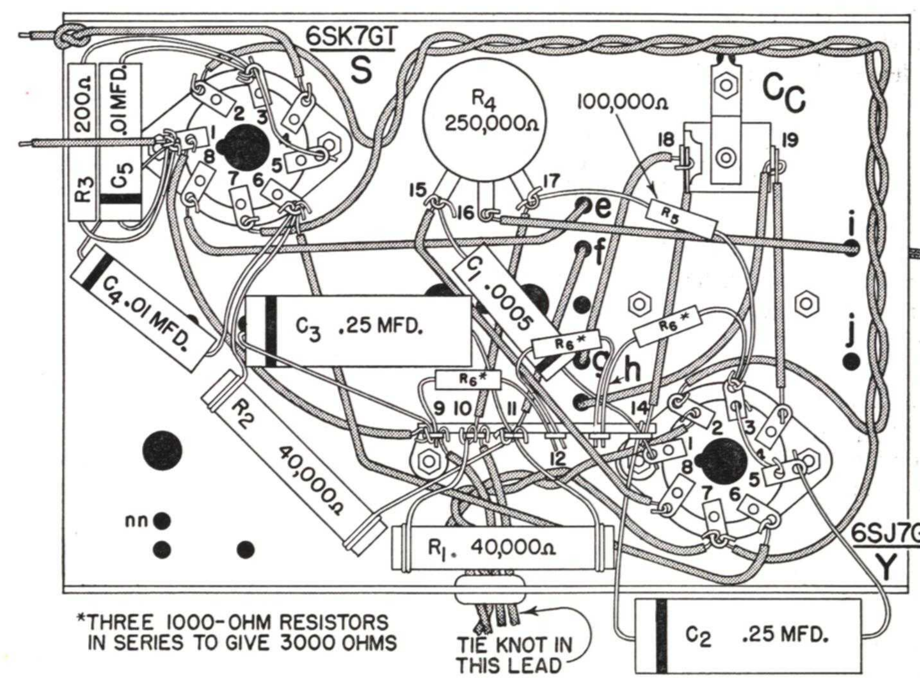


FIG. 5. Semi-pictorial wiring diagram showing how the bottom of the experimental chassis should appear after you have made all connections for the r.f. amplifier and C bias detector stages used in Experiment 51. Observe that in order to obtain a 3000-ohm resistance between terminal *9* and terminal *3* of socket *Y*, three 1000-ohm resistors are connected in series, using terminals *12* and *13* merely as anchor points for the series connections. Note also that all filament leads are twisted together to prevent radiation of a.c. hum signals. Use particular care to make sure that the leads of 40,000-ohm resistors R_1 and R_2 do not touch in the vicinity of terminals *10* and *11*. CAUTION: After completing the wiring, examine terminals *10, 11, 12* and *13* carefully to make sure they are not grounded to the chassis by surplus solder. To remove surplus solder, hold the chassis ABOVE the soldering iron SO SOLDER WILL FLOW DOWN from the lug to the tip of the soldering iron.

each joint; thus, if the semi-pictorial diagram in Fig. *5* shows two or more wires on a particular terminal, you can either wait until all of these wires have been connected before soldering them or make a temporary soldered hook joint with the first wire and make soldered lap joints for the other wires.

a. Cut two 12-inch lengths of hook-up wire and twist them together, leaving about 1½ inches of wire at each end untwisted. Connect one pair of wire ends to terminals *2* and *7* of socket *S*, and connect the other pair of wire ends to terminals *2* and *7* of socket *Y*, bringing the twisted wire around the potentiometer and trimmer condenser C_C as indicated in Fig. *5*.

b. Cut two 14-inch lengths of hook-up wire and twist them together so as to leave about 1½ inches of wire at each end untwisted. Bring the twisted wires through the rubber grommet in hole *k* from the outside, and connect these wires to terminals *2* and *7* of socket *Y*. This completes filament connections to both sockets.

c. Cut a 12-inch length of hook-up wire, push it through the rubber grommet from the outside, and connect this wire to terminal *9*.

d. Cut another 12-inch length of hook-up wire, push it through the grommet, and connect it to terminal *10*. Tie a simple knot about 1½ inches from the other end of this wire, to identify it as the *B+* lead.

e. Connect terminal *1* of socket *S* to terminal *9*.

f. Connect terminal *1* of socket *Y* to terminal *14*.

g. Connect terminal *6* of socket *S* to terminal *6* of socket *Y*, bringing the wire around the terminal strip in the manner indicated in Fig. *5*.

h. Connect together terminals *3* and *5* of socket *S* with a short piece of bare wire.

i. Connect a 200-ohm resistor between terminals *1* and *3* of socket *S*.

At this time, locate the three paper condensers (one .0005-mfd. and two .01-mfd. units) supplied in Radio Kit 6RK and shorten their leads with side-cutting pliers so that they are each about 2 inches long.

j. Connect a .01-mfd. condenser between terminals *1* and *3* of socket *S*.

k. Connect a .01-mfd. condenser between terminals *1* and *6* of socket *S*.

l. Connect terminal *10* to potentiometer terminal *17*.

m. connect terminal *11* to the *red* terminal of the antenna coil, running the wire through chassis hole *f*.

n. Connect a .25-mfd. condenser between terminals *9* and *11*.

o. Connect a 40,000-ohm resistor between terminal *6* of socket *S* and terminal *11*.

p. Connect a 40,000-ohm resistor between terminals *11* and *10*.

q. Connect terminal *8* of socket *S* to the *blue* terminal of the antenna coil, running the wire through chassis hole *e*.

r. Connect a 6-inch length of hook-up wire to terminal *1* of socket *S*, allowing the wire to project out through the open end of the chassis. This will serve as the grounded r.f. input lead.

s. Connect an 8-inch length of hook-up wire to terminal *4* of socket *S*, bring this wire out through the open end of the chassis, and tie a simple knot about 1½ inches from the end of the lead to indicate that it is the hot r.f. input lead. This completes the connections for socket *S*.

t. Connect together terminals *3* and *5* of socket *Y*.

u. Connect a .25-mfd. condenser between terminal *5* of socket *Y* and terminal *14*.

v. Connect a 100,000-ohm resistor between potentiometer terminal *17* and terminal *3* of socket *Y*.

w. Connect potentiometer terminal *15* to terminal *8* of socket *Y*.

x. Connect a .0005-mfd. condenser between terminal *14* and potentiometer terminal *15*.

y. Connect trimmer condenser terminal *18* to the *black* terminal of the antenna coil, bringing the wire through chassis hole *g*.

z. Connect trimmer condenser terminal *18* to terminal *14*.

aa. Connect trimmer condenser terminal *19* to the *green* terminal of the antenna coil, through hole *h*.

bb. Connect trimmer condenser terminal *19* to terminal *4* of socket *Y*.

cc. Connect a 3000-ohm resistance between terminal *3* of socket *Y* and terminal *9*, by connecting one 1000-ohm resistor between terminals *9* and *12*, connecting another 1000-ohm resistor between terminals *12* and *13*, and connecting the third 1000-ohm resistor between terminal *13* and terminal *3* of socket *Y*.

dd. Connect a 5-inch length of hook-up wire to potentiometer terminal *16*, and bring this wire up through chassis hole *i* for use as the ungrounded a.f. output lead.

ee. Connections under the chassis should now appear as shown in Fig. *5*, so check your own work carefully against this diagram, working from left to right in a logical manner so as to check each terminal in turn and be sure it has the correct number of leads on it, going to the correct point. Adjust resistors and condensers carefully to prevent bare leads from touching when they go to different terminals. Be sure there are no lumps of solder grounding any of the potentiometer terminals (*15, 16* and *17*) to the chassis.

Step 3. To connect your modulated r.f. signal generator to the r.f. amplifier and detector, and to make necessary connections to the power pack, first connect to output terminals *1* and *2* of the power pack the twisted leads which come from the signal generator chassis and the experimental chassis, so as to supply filament voltage to all tube sockets.

Connect to output terminal *5* of the power pack the two power supply leads, one from each chassis, which have knots in their ends.

Connect to output terminal *4* of the power pack the remaining two leads which come out of the rubber grommets on their respective chassis units.

Locate the hot r.f. input lead which comes out through one end of the experimental chassis (it has a knot and goes to terminal *4* of socket *S*), and connect it to the hot r.f. output lead of the signal generator (this lead also has a knot, and goes to the *yellow* terminal of the s.g. coil). Make a temporary soldered lap or hook joint.

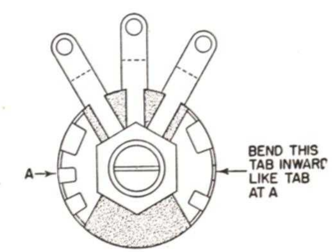


FIG. 5A. Bend locking tab of 250,000-ohm potentiometer inward as shown here.

Connect the grounded r.f. output lead of the signal generator (the lead from terminal *14*) to the grounded r.f. input lead on the experimental chassis (the lead going to terminal *1* of socket *S*).

Insert the type 6SJ7GT tube in socket *Y*. Insert the type 6SK7GT tube in socket *S*. Check the tubes on the signal generator and power pack chassis units to be sure these tubes are firmly seated in their respective sock-

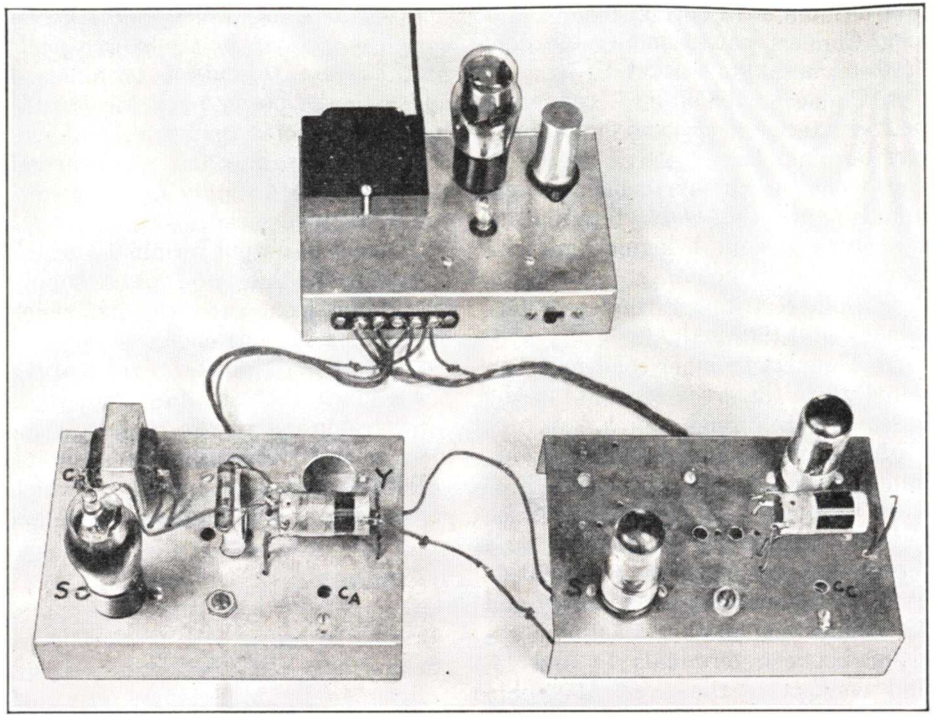


FIG. 6. When you complete Step 3 in Experiment 51, your apparatus should appear as shown here.

ets. Your apparatus should now appear as shown in Fig. *6*.

Step 4. To measure the d.c. plate, screen grid and control grid voltages for each tube on your experimental chassis, first rotate the shaft of the 1000-ohm potentiometer on the signal generator chassis as far as it will go in a counter-clockwise direction, so that the r.f. voltage being applied to the input of the r.f. amplifier stage on the experimental chassis will be zero. This prevents r.f. signals from interfering with your d.c. voltage measurements. The settings of the trimmer condenser on the signal generator chassis and the trimmer condenser and potentiometer on the experimental chassis do not matter for the d.c. voltage measurements, so leave these wherever they happen to be until you receive instructions for adjusting them.

Prepare your N.R.I. Tester for d.c. voltage measurements in the usual manner, as instructed in previous manuals.

Measure the d.c. plate voltage of the 6SK7GT tube (black clip on chassis, red clip on terminal *8* of socket *S*), and record your result in Table *51*.

Measure the d.c. screen grid voltage of the 6SK7GT tube (black clip on chassis, red clip on terminal *6* of socket *S*), and record your result in Table *51*.

Measure the d.c. control grid voltage (the C bias voltage) of the type 6SK7GT tube (black clip on terminal *4* of socket *S*, red clip on terminal *5* of socket *S*), and record your result in Table *51*. Since an up-scale reading is obtained here when the black or negative clip is on the control grid (terminal *4*), you know that the control grid is negative with respect to

the cathode, and should consequently place a minus sign ahead of your measured control grid voltage value. (Note: This grid bias voltage could just as well be measured between terminal *5* of socket *S* and the chassis; try this if you like.)

Measure the d.c. plate voltage of the 6SJ7GT tube (black clip on chassis, red clip on terminal *8* of socket *Y*), and record your result in Table *51*.

NATURE OF MEASUREMENT IN STEP 4	6SK7GT TUBE		6SJ7GT TUBE	
	YOUR VALUE	N.R.I.	YOUR VALUE	N.R.I.
D.C. PLATE VOLTAGE IN VOLTS		120		370
D.C. SCREEN GRID VOLTAGE IN VOLTS		75		75
D.C. CONTROL GRID VOLTAGE IN VOLTS		-1.5		-12

	STEP 6	STEP 7		STEP 8
	R.F. OUTPUT VOLTAGE IN VOLTS WITHOUT DETECTOR	R.F. OUTPUT VOLTAGE IN VOLTS WITH DETECTOR	MAXIMUM R.F. OUTPUT VOLTAGE IN VOLTS WITH DET.	A.F. OUTPUT VOLTAGE IN VOLTS OF DETECTOR
YOUR VALUE				
N.R.I. VALUE	3 x V 12.6	V 1.5	3 x V 9.6	30 x V 45

TABLE 51. Record your results here for Experiment 51, in which you make voltage measurements in an r.f. amplifier stage and C bias detector stage.

Measure the d.c. screen grid voltage of the type 6SJ7GT tube (black clip on chassis, red clip on terminal *6* of socket *Y*), and record your result in Table *51*.

Measure the d.c. control grid voltage of the 6SJ7GT tube (black clip on chassis, red clip on terminal *5* of socket *Y*), and record your result in Table *51*.

Step 5. To listen to the output of your C bias detector stage while feeding into it an a.f.-modulated r.f. signal, first prepare the N.R.I. Tester for LISTENING TO AUDIO SIGNALS, as described in a previous manual, by removing the U-shaped jumper from the *PHONE* jacks and inserting the phone cord tips. Set the selector switch at *100* × *V*. With the test probes in the V_{AC} jacks, place the black clip on the chassis and the red clip on the hot a.f. output lead (this comes up through chassis hole *i*, near the antenna coil).

Adjust the two trimmer condensers (C_A on the signal generator chassis and C_C on the experimental chassis) to a setting one turn off from maximum capacity, by rotating each adjusting screw in turn in a clockwise direction as far as it will go, then backing up one complete turn in a counter-clockwise direction.

Trimmer condenser adjustments are *always* made from the top of the chassis, through the holes (*x* and *u*) provided for this purpose. The adjusting screw of each trimmer is grounded to the chassis through the mounting bracket, so no harm can occur if the screwdriver blade touches the chassis during trimmer adjustments.

Now rotate the *potentiometers* as far as they will go in a clockwise direction, so as to set both for maximum output.

Turn on the power pack and the N.R.I. Tester, wait half a minute, then lower the selector switch setting until you obtain a noticeable meter deflection. Now adjust trimmer condenser C_C on the experimental chassis for maximum phone volume while watching the meter. Switch to a higher voltage range each time the meter pointer approaches the full-scale value of 5.5 on the *AC* scale. Adjust carefully until maximum volume is obtained; the meter reading will then also be a maximum.

Do not press down on the screwdriver while adjusting the trimmer condenser; simply let the screwdriver rest in the slot of the adjusting screw, and rotate the screwdriver slowly with the fingers until maximum headphone volume is obtained.

With trimmer condenser C_C on the experimental chassis tuned to resonance so it is set for maximum volume, rotate the potentiometer on this chassis back and forth a few times with a screwdriver to determine its effect upon the volume. There is no need to record any of the results for this step. Turn off the power pack and the N.R.I. Tester now.

Step 6. To measure the r.f. output voltage of your r.f. amplifier stage when an r.f. input voltage of exactly 1 volt is being fed into this stage and the detector stage is disconnected, first pull out the phone cord tips and replace the U-shaped jumper in the *PHONE* jacks. Now place the test clips on the two leads which connect the signal generator chassis to the experimental chassis, with the red clip going to the leads having the knots. Set the selector switch at *V*, then review the instructions given in the previous manual for making r.f. voltage measurements.

Turn on the power pack and the N.R.I. Tester, arrange the test leads so they are at least an inch apart and several inches away from all objects so as to reduce the capacity between leads, then adjust the potentiometer on the signal generator chassis until the meter indicates an r.f. voltage of exactly 1 volt. Your signal generator is now feeding 1 volt r.f. to the input of the r.f. amplifier stage. Turn off the N.R.I. Tester and the power pack without changing the settings of any adjustments.

It is a good idea to check the zero setting of the meter whenever you have to read the meter accurately in the vicinity of 1 volt; this can be done simply by removing the red probe from the tester and noting if the pointer returns to zero when the meter is tapped. If the pointer does not go exactly to zero, touch the calibrating clip to the —4½C terminal for a few seconds as instructed in a previous manual, for the shift in calibration may be only temporary and due to previous overloading of the meter. If the pointer is still off from zero when the calibrating clip is returned to —9C and the meter is tapped, bring it exactly to zero by adjusting the zero-correcting knob at the back of the meter.

Turn over the experimental chassis, unsolder from trimmer condenser terminal *19* the lead which goes to terminal *4* of socket *Y*, and connect this unsoldered lead temporarily to terminal *18* of the trimmer condenser (or to terminal *14*) by means of a soldered lap joint, so as to ground the control grid of the detector stage temporarily to the chassis.

Set the experimental chassis in an upright position, place the red clip on the *green* terminal of the antenna coil, place the black clip on the chassis, and set the selector switch at *3* × *V*, so that you are prepared to

measure the r.f. voltage across resonant circuit L_4—C_C.

Turn on the power pack and the N.R.I. Tester, then adjust trimmer condenser C_C on the experimental chassis slowly and carefully until you obtain a maximum meter deflection. This adjustment is highly critical, and considerable patience will be required to get the condenser set exactly at the point which gives maximum r.f. voltage.

Having secured the correct trimmer condenser setting, read the meter on the *AC* scale, multiply the reading by 3, and record your result in Table *51* as the r.f. output voltage in volts when the detector circuit is not connected to the r.f. amplifier output. Turn off the N.R.I. Tester and the power pack.

When measuring r.f. voltages, keep the N.R.I. Tester leads well away from other parts, keep your hands away from the leads and from both the signal generator and experimental chassis units, and try to keep the tester leads approximately the same distance apart (at least 1 inch apart) throughout a series of measurements. These precautions are necessary because the capacity between the two tester leads adds to the capacity already existing between the terminals at which the r.f. voltage is being measured, and any variation in the capacity introduced by the N.R.I. Tester after adjusting the trimmer condenser will detune the circuit under measurement.

Step 7. To measure the r.f. output voltage of the amplifier stage for an r.f. input of 1 volt when the detector stage is connected across the r.f. amplifier output, first restore the detector stage connections by returning to terminal *19* the lead from terminal *4* of socket *Y* which you temporarily grounded to terminal *18* of trimmer condenser C_C (or to terminal *14*) on the experimental chassis. Do not change any adjustments. Now restore the experimental chassis to its upright position, make sure the test clips are still on the *green* terminal and the chassis, set the selector switch at *V*, then turn on the power pack and the N.R.I. Tester, measure the r.f. voltage for this set-up, and record your result in Table *51* as the r.f. output voltage in volts with the detector circuit connected.

Without turning off your apparatus, adjust trimmer condenser C_C on the experimental chassis with a screwdriver until you secure a maximum meter deflection. Adjust carefully for maximum deflection, switching to higher voltage ranges as necessary, then read the meter and record your result in Table *51* as the *maximum* r.f. voltage in volts with the detector circuit connected. Turn off the N.R.I. Tester and the power pack now.

Step 8. To measure the a.f. output voltage of your detector stage, leave the black clip on the chassis, but move the red clip to the hot a.f. output lead on the experimental chassis (the lead coming up through hole *i*, near the antenna coil). Set the selector switch at *3* × *V*, then turn on the power pack, turn on the N.R.I. Tester a short time later, and adjust trimmer condenser C_C on the experimental chassis until you obtain a maximum meter reading. Switch to the *30* × *V* range when the reading becomes too high for the *3* × *V* range. Make this trimmer condenser adjustment very carefully, for it is highly critical.

With the trimmer condenser adjusted for maximum output, read the meter and record your result in Table *51* as the a.f. output voltage of the detector in volts. Turn off the N.R.I. Tester and the power pack.

Discussion: The d.c. voltage measurements which you make in Step 4 should show that the control grid, screen grid and plate electrodes of both tubes on the experimental chassis are getting d.c. voltages, and the values of these voltages should check with the following analysis.

A study of the schematic circuit diagram in Fig. *3* indicates that the d.c. plate voltage of the 6SK7GT r.f. amplifier tube will be less than the power pack d.c. output voltage between terminals *4* and *5*, due to the voltage drop across 40,000-ohm resistor R_1. This voltage drop is due to the plate current of the r.f. amplifier tube and the screen grid currents of both tubes.

Note also that the screen grid currents of both tubes flow through 40,000-ohm resistor R_2. This means that both screen grid voltages will be lower than the plate voltage of the r.f. amplifier tube.

Plate and screen grid currents for the r.f. amplifier tube also flow through the 200-ohm cathode resistor R_3, producing across this resistor an additional small voltage drop which serves as the C bias for the r.f. amplifier tube and also serves to lower the plate and screen grid electrode voltages.

The plate voltage for the 6SJ7GT tube in the detector stage is very nearly equal to the power pack d.c. output voltage, for this detector circuit is automatically biased to cut-off by the voltage drop across 3000-ohm resistor R_6, and very little plate current flows. This small plate current value flowing through 250,000-ohm potentiometer R_4 produces only a small voltage drop across this potentiometer, thus reducing the supply voltage only a small amount.

The C bias voltage of the detector stage is determined by the ohmic value of resistor R_6 and by the amount of current flowing through this resistor. Two distinct currents flow through R_6; one is due to the plate and screen grid currents of the detector tube, and the other is due to the current "bled" from the power pack through 100,000-ohm resistor R_5, which is in series with R_6 across power pack output terminals *4* and *5*.

The d.c. voltage measured between the cathode of a tube and the chassis is the C bias voltage, for there is d.c. continuity between the control grid and the chassis in the circuits you are using.

A .25-mfd. condenser (C_2) across resistor R_6 is a low-reactance path for audio signals around this resistor.

Listening Test. When you make the audio listening test called for in Step 5, you should be able to hear clearly the audio tone which is produced by the a.f. oscillator portion of your signal generator. You are then using your N.R.I. Tester as an *aural indicator*. Varying the setting of 250,000-ohm potentiometer R_4 should vary the volume of this tone, thereby demonstrating the action of a volume control like that in receivers.

When you set both trimmer condensers approximately to the same positions, then adjust the trimmer condenser on the experimental chassis carefully for maximum output volume, you are really tuning the detector input resonant circuit on your experimental chassis to the same radio frequency being generated by your signal generator.

R.F. Gain. In Step 6, you first adjust the output potentiometer on the signal generator chassis so that this signal generator delivers exactly a 1-volt r.f. signal to the input of the r.f. amplifier stage. The detector stage is disconnected for the first test, in order that you can measure the gain of the r.f. amplifier stage by itself. (Moving the control grid lead of the detector tube from terminal *19* to terminal *18* prevents the detector stage from loading the resonant circuit, but d.c. electrode voltages for the detector tube remain normal so as not to upset

circuit voltages through a change in the drain on the power pack.)

In the case of N.R.I. measurements for Step 6, an r.f. input voltage of 1 volt for the r.f. amplifier stage gave an r.f. output voltage of 12.6 volts across resonant circuit L_4-C_C when this circuit was tuned to resonance. This means that the gain of the r.f. amplifier stage is 12.6 (gain is equal to output voltage divided by input voltage, and the input voltage in our case is 1 volt).

This gain value is quite low for a 6SK7GT tube, since this tube can, under normal conditions, provide a gain as high as 150. The reason for this low gain is simply that the primary winding of the antenna coil which we are using as an r.f. output transformer has too few turns for effective coupling. More turns on this primary winding would increase the plate load resistance of the 6SK7GT tube and at the same time increase the coupling, so that a greater r.f. voltage would be induced in the resonant circuit. In another experiment, resonant circuit L_4-C_C will be moved to the plate circuit of the r.f. amplifier stage, and greater gain will be observed.

Detuning and Loading Effects of Detector. Having measured the gain of the r.f. amplifier stage, you reconnect the detector stage without changing tester or circuit conditions, in order to demonstrate that the detector detunes the resonant circuit. Note that the N.R.I. value of r.f. output voltage for the r.f. amplifier stage dropped from 12.6 volts to 1.5 volts when the detector stage was connected again. Retuning trimmer condenser C_C to resonance served to increase the r.f. output voltage (to 9.6 volts in the case of the N.R.I. values), but did not bring it back to the original value obtained without the detector. Obviously, the detector has some other effects in addition to detuning.

As you learned in previous experiments, a vacuum tube has an input capacity which depends upon the true gain of the stage as well as upon the construction of the tube and upon stray circuit capacities. When you retune condenser C_C, you remove the detuning effects of this detector input capacity.

The fact that retuning does not bring the gain back to its initial maximum value can be explained only by the fact that the detector acts as a load upon the r.f. amplifier. The inter-electrode capacity between the grid and plate of the detector tube not only raises the input capacity, but also reflects back into the grid circuit a resistance which will act as a load on the input if the plate of the detector tube is capacitive. If the plate circuit of the detector tube is inductive, however, this reflected resistance would appear as a negative resistance in the input circuit, causing regeneration. In the detector circuit employed in this experiment, condenser C_1 (Fig. *3*) makes the plate capacitive, and consequently we secure a loading effect.

The removal of C_1 from the detector circuit of Fig. *3* would not necessarily create regeneration, for stray plate circuit capacities may be sufficient to make the plate capacitive, but this condenser is necessary in order to prevent r.f. voltages from being developed across the plate load resistor.

Additional loading is provided by the flow of rectified grid current in the grid circuit of the detector, for even though the r.m.s. value of r.f. voltage applied to the grid is lower than the cut-off bias voltage (9.6 volts r.f. is lower than —12 volts C bias in the case of N.R.I. values), the peaks of the applied r.f. signal will swing the grid of the detector tube positive and cause grid current flow.

Thus, we find that our C bias detector does have a certain loading effect upon the preceding r.f. stage, even though this type of detector is ordinarily considered to have no loading effect. The explanation for this is simply that we are feeding into the detector a higher r.f. voltage than would normally be employed in radio receiver design.

Optional Step. If you desire, you can readily prove for yourself that a C bias detector has negligible loading effect upon the preceding r.f. stage when operated under normal conditions. All you need to do is repeat three of the measurements called for in Steps 6 and 7, in the following manner.

Connect your N.R.I. Tester to measure the r.f. output voltage of the amplifier stage, first with the detector stage disconnected by unsoldering from *19* the lead which goes to *4* of *Y*, and grounding this lead temporarily to *18*). Use the $3 \times V$ range of the tester and adjust the potentiometer on the signal generator chassis until you obtain an r.f. output voltage reading of 6 volts.

Next, restore the detector connection without retuning the trimmer condenser on the experimental chassis, and measure the r.f. output voltage. It will be considerably below 6 volts. Now retune trimmer condenser C_C on the experimental chassis for a maximum meter reading. If the voltage rises approximately to 6 volts now, you have proved for yourself that a C bias detector normally has no appreciable loading effect upon the preceding amplifier stage.

Try Out Your Own Ideas. In the remaining experiments, you will often be able to make extra tests when questions arise concerning circuit behavior. You will secure just as much benefit from experiments worked out yourself in this manner as from those for which we give detailed instructions.

Before making circuit changes, however, be sure to analyze what you intend to do, in order to prevent damage to tubes and other parts. By now, you have had sufficient experience with practical radio circuits to know that you cannot safely remove the negative C bias from a tube which is being operated with a high plate voltage. Likewise, you know that partial or complete short circuits across the power pack will draw excessive current and possibly damage power pack parts. In general, signal circuit changes which do not appreciably change d.c. electrode voltages can be made safely at any time.

Percentage Modulation. According to the N.R.I. values, the maximum r.f. voltage in volts which is fed into the detector is 9.6 volts, and the maximum a.f. output voltage obtained for this input voltage is 45 volts. This does not mean, however, that we can divide the a.f. output voltage by the r.f. input voltage to secure a value equal to the gain of the detector tube. We must divide the a.f. output by the a.f. component in the r.f. input, and this means taking into account the percentage modulation. Let us see how this can be done.

The N.R.I. Tester responds to peak r.f. voltages, and is calibrated to read the r.m.s. values corresponding to these peak values. This means that with the measured N.R.I. detector input voltage of 9.6 volts, the peak r.f. voltage will rise as high as 1.4×9.6, or 13.4 volts. If 100% modulation existed with this 13.4-volt peak value, the envelope of this modulated r.f. voltage would have a peak value of 6.7, for the audio signal would cause

the r.f. voltage to vary between the peak r.f. value and zero.

With a peak value of 6.7 volts for the audio modulation on the carrier at the detector input, the effective or r.m.s. value of audio input voltage will be $6.7 \div 1.4$, which is about 4.8 volts. With the N.R.I. 45-volt a.f. output, the gain of the detector stage would be $45 \div 4.8$, or 9.4 if we had 100% modulation.

The lower the percentage modulation of the signal produced by the signal generator, the lower is the audio voltage at the detector input for a given r.f. input value. The percentage modulation of the signal generator when constructed according to our instructions is considerably lower than 100%, and consequently the a.f. detector input voltage is considerably lower than the value we just calculated on the basis of 100% modulation. This means that the gain of the detector stage is actually considerably higher than the value of 9.4 we just calculated on the basis of 100% modulation. If we had only 10% modulation, the a.f. input voltage would be 1/10 of the calculated value, making the gain of the C bias detector stage ten times the computed value of 9.4, or about 94.

Instructions for Report Statement No. 51. A detector is a vacuum tube circuit which responds to the amplitude of the r.f. input signal. In other words, the d.c. voltage drop across the detector load resistor (R_4) varies as we vary the amplitude of the r.f. signal. We can prove this by removing temporarily the modulation from the r.f. signal produced by the signal generator, and using the potentiometer on the signal generator chassis to vary the r.f. output voltage of this unit. Then, with the N.R.I. Tester connected as a d.c. voltmeter, we can measure the d.c. voltage across the detector plate load resistor R_4 and note how this voltage varies as the r.f. input voltage is varied.

To remove the modulation from the signal generator, simply short together the *G* and *F* terminals on the audio transformer with a short length of hook-up wire, using temporary soldered lap joints. Now turn the experimental chassis upside-down, place the red clip on potentiometer terminal *17*, place the black clip on potentiometer terminal *15*, prepare the N.R.I. Tester for d.c. voltage measurements, set the selector switch at $100 \times V$, turn on all apparatus and wait for tubes to warm up, choose an appropriate voltage range for the tester, then rotate the signal generator potentiometer to its extreme counter-clockwise position, corresponding to zero r.f. voltage, and note the meter reading; rotate the potentiometer now to its extreme clockwise position, corresponding to a maximum r.f. voltage, and again note the meter reading. You now have enough information to enable you to answer Report Statement No. 51. Turn off all apparatus.

EXPERIMENT 52

***Purpose:* To connect a diode detector circuit to the output of the r.f. amplifier stage; to show that this diode circuit will detect a modulated r.f. signal and will also produce a d.c. voltage which is proportional to carrier level; to show that a diode detector has both detuning and loading effects upon the preceding r.f. amplifier stage; to show that a diode load potentiometer will serve as a volume control.**

Step 1. To convert your C bias detector circuit into a diode detector circuit as shown in Fig. 7, make the following changes on your experimental chassis:

a. With all apparatus turned off but with the three chassis units still connected together, first remove the lead with which you shorted terminals *G* and *F* of the audio transformer on the signal generator chassis.

b. The remaining changes are all made on the experimental chassis. Remove the lead which connects terminal *6* of socket *S* to terminal *6* of socket *Y*.

c. Remove the short length of bare wire going between terminals *3* and *5* of socket *Y*.

d. Remove the .25-mfd. paper condenser which is connected between terminal *14* and terminal *5* of socket *Y*.

e. Remove the 1000-ohm resistor connected between terminals *9* and *12*, the 1000-ohm resistor connected between terminals *12* and *13*, and the 1000-ohm resistor connected between terminal *13* and terminal *3* of socket *Y*.

f. Remove the .1-megohm resistor which is connected between potentiometer terminal *17* and terminal *3* of socket *Y*.

g. Remove the lead which connects trimmer condenser terminal *18* to terminal *14*.

h. Unsolder the lead which is on terminal *8* of socket *Y*, and connect this lead instead to trimmer condenser terminal *18*.

i. Unsolder from terminal *10* the lead which comes from potentiometer terminal *17*, and connect this lead instead to terminal *9*.

j. Connect terminal 5 of socket *Y* to terminal *14*, thereby grounding the cathode of the detector tube.

k. Connect together terminals *3*, *4*, *6* and *8* of socket *Y*. This connects together the control grid, screen grid, suppressor grid and plate of the type 6SJ7GT pentode tube, thereby converting this tube into a diode.

l. Unsolder the hot a.f. output lead from potentiometer terminal *16*, and connect this lead to terminal *13*; leave it in hole *i*, just as before.

m. Connect the .25-mfd. condenser between terminals *13* and *16*.

Step 2. To make voltage measurements in your r.f. amplifier stage and diode detector stage, first make sure that the experimental chassis, the signal generator chassis and the power pack chassis are still connected together exactly as they were for Experiment 51.

To adjust the signal generator so that it delivers exactly 1 volt r.f. to the input of the 6SK7GT r.f. amplifier stage, first remove the type 6SJ7GT tube from its socket. Place the red clip on the knotted input lead for the experimental chassis, place the black clip on the experimental chassis, prepare the N.R.I. Tester for r.f. voltage measurements, turn on the power pack, turn on the N.R.I. Tester, then adjust the potentiometer on the signal generator chassis until the meter reads exactly 1 volt on the *AC* scale when using the *V* range.

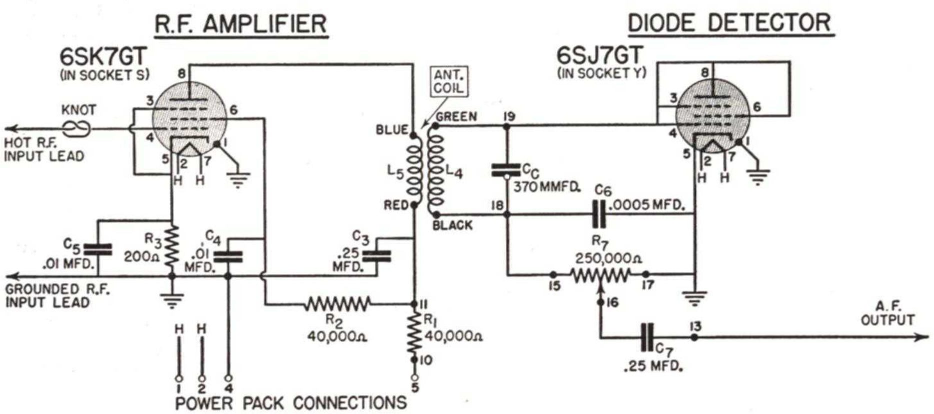


FIG. 7. Schematic circuit diagram for the r.f. amplifier and diode detector stages which you set up for Experiment 52. Note that the 6SJ7GT pentode is used here as a diode by connecting all three grids to the plate. The a.f. output of the detector stage is obtained between the a.f. output lead and the chassis.

	MAXIMUM R.F. OUTPUT VOLTAGE IN VOLTS WITHOUT DIODE DETECTOR	R.F. OUTPUT VOLTAGE IN VOLTS WITH DIODE DETECTOR	MAXIMUM R.F. OUTPUT VOLTAGE IN VOLTS WITH DIODE DETECTOR	A.F. OUTPUT VOLTAGE OF DIODE DETECTOR STAGE IN VOLTS	D.C. VOLTAGE ACROSS DIODE LOAD FOR R.F. INPUT OF 1 VOLT	D.C. VOLTAGE ACROSS DIODE LOAD FOR ZERO R.F.
YOUR VALUE						
N.R.I. VALUE	3 x V 13.8	V 1.5	3 x V 11.1	V 3.5	13.5	.8

TABLE 52. Record your results here for Experiment 52, in which you make voltage measurements in an r.f. amplifier stage and diode detector stage.

To determine the gain of your r.f. amplifier stage, connect the N.R.I. Tester across the resonant output circuit of the r.f. amplifier by placing the red clip on the *green* terminal of the antenna coil and placing the black clip on the *black* terminal of the antenna coil, so you can measure the r.f. voltage here. Turn on all apparatus, and adjust trimmer condenser C_C on the experimental chassis until you obtain a maximum meter reading. Keep your hands away from the test leads while making this adjustment, and keep the test leads separated by at least 1 or 2 inches for their entire length during the adjustments and measurements. Record your final r.f. voltage reading in Table *52* as the maximum r.f. output voltage in volts without the diode detector. Do not turn off the apparatus.

Replace the type 6SJ7GT tube in socket *Y* on the experimental chassis **so as to connect the diode detector** circuit to the output of the r.f. stage, measure the r.f. voltage across resonant circuit L_4-C_C again, and record your result in Table *52* as the r.f. output voltage in volts with the diode detector connected. Do not turn off your apparatus yet.

Tune trimmer condenser C_C on the experimental chassis for a maximum meter reading, switching to a higher voltage range when necessary, then record your result in Table *52* as the maximum r.f. output voltage in volts with the diode detector connected. Turn off the apparatus now.

Place the red clip on the a.f. output lead (coming through hole *i*), place the black clip on the experimental chassis, turn on the apparatus, rotate the 250,000-ohm potentiometer on the experimental chassis as far as it will go in a clockwise direction so as to secure maximum a.f. output voltage, set the selector switch at *V*, adjust trimmer condenser C_C on the experimental chassis for a maximum meter reading, and record your result in Table *52* as the a.f. output voltage of the diode detector stage.

Prepare the N.R.I. Tester for audio listening tests by plugging the headphone into the *PHONE* jacks, listen to the audio tone for a short time, then rotate the shaft of the 250,000-ohm potentiometer on the experimental chassis in a *counter-clockwise* direction so as to reduce the a.f. output voltage of the diode detector, and note how this affects the volume of the tone heard in the headphone. Return this potentiometer to its maximum clockwise position so as to restore maximum output volume, then turn off the N.R.I. Tester and the power pack, remove the headphone tips, and replace the U-shaped jumper in the *PHONE* jacks.

Prepare the N.R.I. Tester for d.c. voltage measurements, then measure the d.c. voltage across the 250,000-ohm diode load potentiometer by placing the red clip on the experimental chassis and placing the black clip on the *black* terminal of the antenna coil. Do not change any trimmer condenser or potentiometer settings. Record your result in Table *52* as the d.c. voltage in volts across the diode load.

Reduce the r.f. input voltage to the r.f. amplifier stage now by rotating the signal generator potentiometer in a counter-clockwise direction slowly, and note how this change affects the d.c. voltage across the diode load potentiometer as indicated by the meter in the N.R.I. Tester. When you have rotated the signal generator potentiometer as far as it will go in a counter-clockwise direction, so that the r.f. voltage is down to zero, note that the meter still indicates a d.c. voltage across the diode load. Read this voltage as indicated by the meter, and record your result in Table *52* as the d.c. voltage in volts across the diode load when the r.f. input voltage is zero.

To prove that this small d.c. voltage measured across the diode load is due to something besides r.f. voltage, remove the type 6SK7GT tube from socket *S* on the experimental chassis so as to open the r.f. amplifier stage. Now there is no chance whatsoever for stray r.f. signals to travel from the signal generator to the diode detector. Note the meter reading again; it should be exactly the same as for the previous condition. Turn off the apparatus.

Discussion: The value which you record for the maximum r.f. output voltage without the diode detector corresponds to the gain of the r.f. amplifier stage, for the r.f. input voltage to this stage is 1 volt. Your measured value may not agree with the corresponding value obtained in the previous experiment, for it is difficult to adjust the r.f. input voltage accurately to 1 volt.

When you connect the diode detector across the output of the r.f. amplifier stage by inserting the type 6SJ7GT tube in socket *Y*, the r.f. voltage measured across the resonant circuit should drop considerably, due to the loading and detuning effects of the detector stage. Thus, the N.R.I. value drops from 13.8 without the diode detector to 1.5 volts with the diode detector connected.

Retuning the resonant secondary circuit to resonance by adjusting trimmer condenser C_C eliminates the detuning effect, leaving only the loading effect of the detector. Retuning brought the N.R.I. value of r.f. voltage across the resonant circuit up to 11.1 volts. This retuning involves reducing the capacity of C_C (by rotating the adjusting screw in a counter-clockwise direction), for the diode plate-cathode capacity increases the total capacity across the resonant circuit.

When electrons are flowing from the cathode to the plate of a diode detector tube, a definite d.c. resistance exists between these two electrodes. In the circuit you are now employing (Fig. 7), this d.c. resistance acts in series with the 250,000-ohm diode load potentiometer across the resonant circuit. The resistance of a diode is usually somewhere between 25,000 and 50,000 ohms, so that we have ap-

proximately a 300,000-ohm load across the resonant circuit. It is this load which prevented the N.R.I. value of r.f. output voltage from rising any higher than 11.1 volts when the diode detector was connected and the trimmer condenser was retuned to resonance.

The N.R.I. values indicate that the a.f. voltage measured across the diode load is low in comparison to the d.c. voltage across this load. This is a definite indication that the percentage of modulation of the signal produced by the signal generator is quite low, and is probably only a little more than 30%.

When the r.f. input to the detector is removed entirely in the last measurement, the N.R.I. value of d.c. diode load voltage drops to .8 volt. This voltage is due to electrons which travel from the cathode to the anode of the diode detector tube even though there is no voltage on the anode, for electrons move away from the heated cathode in all directions. The electrons which reach the anode flow back to the cathode through the detector load resistor, producing across this resistor the minimum d.c. voltage which you measure.

The fact that the a.f. output voltage of the diode detector is considerably less than the r.f. voltage fed into the detector proves that a diode detector provides no a.f. gain. The output of the diode detector is dependent solely upon the r.f. input voltage level and the percentage of modulation.

The audio listening test which you make in this experiment shows that an a.f. voltage does exist across the diode load, and also shows that the a.f. output can be varied by changing the setting of the diode load potentiometer.

The measurement of the d.c. voltage across the diode load potentiometer shows that the voltage at terminal *15* is negative with respect to the cathode and ground, and shows also that this negative d.c. voltage varies with the r.f. signal input level. This negative d.c. voltage can be used to provide automatic bias for r.f. amplifier stages; you will actually demonstrate this in another experiment.

Instructions for Report Statement No. 52. In one of your regular N.R.I. textbooks dealing with detectors, it was pointed out that the a.f. output voltage of a detector increases with the percentage of modulation. For this report statement, you will perform a simple experiment which proves this basic fact.

In the signal generator which you are now using as a source of modulated r.f. voltage, the audio oscillator employs an 18,000-ohm resistor between the cathode of one of the triode sections and the chassis. By shunting this cathode resistor with a 10,000-ohm resistor, you can lower the cathode resistance and thereby reduce the amount of degeneration which this resistor introduces. As a result, the audio output will increase and the percentage of modulation of the modulated r.f. output signal will increase correspondingly.

Locate the 18,000-ohm resistor which is connected between socket terminals *1* and *8* underneath the signal generator chassis, solder one lead of the 10,000-ohm resistor temporarily to socket terminal *8*, and adjust the other lead so that you can readily place it in contact with the chassis by pushing on the body of the resistor with your finger.

Connect the N.R.I. Tester to measure the a.f. output voltage of the detector stage by placing the red clip on the hot a.f. output lead and placing the black clip on the experimental chassis. Turn on all apparatus, and adjust the signal generator potentiometer to give an a.f. output voltage of 3 volts for this original circuit whereby the cathode resistor is 18,000 ohms.

Now push the free lead of the 10,000-ohm resistor against the signal generator chassis, so that the 10,000-ohm resistor is in parallel with the 18,000-ohm resistor, and hold this lead in position long enough to read the a.f. output voltage indicated by the N.R.I. Tester. Make a note of this voltage value so that you can record it in Report Statement No. 52 after you answer the first part of this report statement. Turn off all apparatus.

EXPERIMENT 53

***Purpose:* To build a grid leak-condenser detector circuit, and show that it will demodulate an a.f.-modulated r.f. signal; to show that a grid leak-condenser detector will effectively demodulate weak signals.**

Preliminary Discussion. In this experiment, we will check the performance of a grid leak-condenser detector employing a pentode tube, and compare it with the performance of the C bias detector assembled in Experiment 51, which also used a pentode tube. Of course, this comparison will also apply for triode detectors, the only essential difference being that triodes give considerably less a.f. output than pentodes.

An inspection of the N.R.I. values recorded in Table *51* shows that when an r.f. voltage of 9.6 volts was fed into a C bias detector circuit, an a.f. output voltage of 45 volts was obtained. This means that the C bias detector delivers about 4.7 volts a.f. output for each volt of r.f. input, because the a.f. output of a C bias detector is more or less proportional to the r.f. input ($45 \div 9.6 = 4.7$).

An r.f. input to the detector of 9.6 volts can hardly be considered a weak signal. Since we are concerned with performance on weak signals in this experiment, we will feed 1 volt of r.f. into the grid leak-condenser detector circuit. We know that this 1 volt r.f. would give approximately 4.7 volts a.f. output in the case of a C bias detector; therefore, if we get more than 4.7 volts a.f. output for the grid leak-condenser detector, we can say definitely that this grid leak-condenser is better than a C bias detector for weak-signal reception.

In this experiment, we will also check the performance of the r.f. amplifier stage when it has a high-impedance plate load, in order to show that a gain of around 100 can be obtained if the plate load has a sufficiently high impedance. We will use a resonant circuit made up of 370-mmfd. trimmer condenser C_C and the secondary of the antenna coil as the high-impedance load.

Step 1. To rewire the apparatus on your experimental chassis according to the circuit of Fig. 8 so as to secure an r.f. amplifier stage with high-impedance load, followed by a grid leak-condenser detector stage, make the following changes in your apparatus:

a. Remove the 10,000-ohm resistor which you temporarily shunted across the 18,000-ohm resistor connected between socket terminals *1* and *8* underneath the signal generator chassis, so as to restore the original signal generator circuit.

b. Remove the two tubes temporarily from the *experimental* chassis, then place this chassis upside-down without disconnecting the wires going to the power pack and the signal generator chassis.

c. Remove the .25-mfd. condenser which is connected between *13* and *16*.

d. Remove the .0005-mfd. condenser which is connected between *14* and *15*.

e. Remove the lead which connects *19* to *4* of *Y*.

f. Unsolder all leads on terminals *3*, *4*, *6* and *8* of socket *Y*.

g. Unsolder from *18* the lead which goes to *15*, and connect this lead to *8* of *Y*.

h. Unsolder from *9* the lead which goes to *17*, and connect this lead instead to *10*.

i. Unsolder the hot a.f. output lead from *13*, and connect this lead instead to potentiometer terminal *16*.

j. Mount a 370-mmfd. trimmer condenser in hole *nn*; identify this condenser as C_D on both sides of the experimental chassis, then identify the condenser terminal nearer the edge of the chassis as *20*, and identify the other terminal as *21*. Set C_D to maximum capacity, as it serves only as a fixed-value plate by-pass condenser in this circuit.

k. Connect *9* to *21*.

l. Connect *20* to *15*.

m. Connect the .0005-mfd. condenser between *13* and *4* of *Y*.

n. Connect a 2-megohm resistor between *13* and *4* of *Y*.

o. Unsolder from *8* of *S* the lead which comes through hole *e*, and solder this lead instead to *13*.

p. Unsolder from *11* the lead which goes through hole *f*, and connect this lead instead to *14*.

q. Connect *18* to *11*.

r. Connect *19* to *8* of *S*.

s. Connect *12* to *6* of *S*.

t. Connect a 100,000-ohm resistor between *12* and *6* of *Y*.

u. Connect a .25-mfd. condenser between *14* and *6* of *Y*.

v. Connect together *3* and *5* of *Y*.

Step 2. To make voltage measurements in your r.f. amplifier stage and grid leak-condenser detector stage, first replace the 6SK7GT and 6SJ7GT tubes in their sockets. Connect and prepare the N.R.I. Tester for measuring the r.f. input voltage to the r.f. amplifier stage (red clip on knotted r.f. input lead, black clip on either chassis). Turn on the apparatus, and adjust the signal generator potentiometer to give an r.f. input voltage of exactly 1 volt to the r.f. amplifier stage.

Next, measure the r.f. voltage across the high-impedance resonant circuit which serves as the plate load for the r.f. stage (red clip on *green* terminal of antenna coil, black clip on chassis), then adjust trimmer condenser C_C for a maximum r.f. voltage reading,

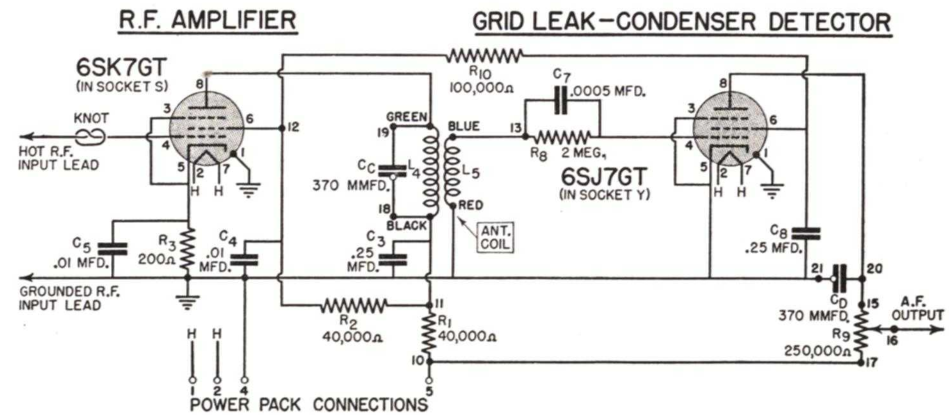


FIG. 8. Schematic circuit diagram for the r.f. amplifier and grid leak-condenser detector stages which you set up for Experiment 53. Trimmer condenser C_D is used here simply as a fixed 370-mmfd. plate by-pass condenser; it is not adjusted once it is set to maximum capacity.

and record your result in Table *53* as the r.f. output voltage in volts of the r.f. amplifier stage.

Measure the r.f. input voltage to the detector stage (red clip on *blue* terminal of antenna coil, black clip on chassis), after readjusting C_C for a maximum r.f. voltage reading, then record your result in Table *53* as the r.f. input voltage in volts to the detector stage.

Measure the a.f. output voltage of the detector stage (red clip on the a.f. output lead coming from *16*, black clip on chassis), after setting the 250,000-ohm potentiometer for maximum a.f. output by rotating clockwise, and adjusting C_C for maximum a.f. output, then record your result in Table *53* as the maximum a.f. output voltage in volts of the detector stage.

Feed the 1-volt r.f. output of the signal generator directly to the input of the grid leak-condenser detector stage, as follows:

Break the connection between the knotted s.g. output and r.f. input leads. Ground the knotted r.f. input lead by connecting it to *1* of *S*. Unsolder from the *blue* terminal of the antenna coil the lead which runs through the chassis to *13*, and connect this unsoldered lead to the knotted s.g. output lead with a 10-inch length of hook-up wire. Do not change any potentiometer or trimmer condenser settings.

Measure the a.f. output voltage of the detector for this 1-volt r.f. input, and record your result in Table *53* as the a.f. output voltage in volts for 1-volt r.f. input.

Without changing any settings, plug the headphone into the N.R.I. Tester. Listen to the audio output signal while you reduce the a.f. output voltage of the detector stage by rotating the 250,000-ohm potentiometer on the experimental chassis counterclockwise, and note how this reduces the volume of the audio signal. Turn off all apparatus.

Discussion: This experiment gives dramatic proof that a pentode tube like the 6SK7GT will provide high gain when used with a high-impedance plate load in an r.f. amplifier stage. The N.R.I. r.f. output value of 111 volts for 1-volt r.f. input means that a gain of 111 was obtained.

The N.R.I. r.f. input voltage to the detector stage, as measured across smaller antenna coil winding L_5, is only 9 volts. This is to be expected, for in the circuit of Fig. *8* we are using the antenna coil as a step-down transformer.

A 9-volt r.f. input to the detector gave an N.R.I. a.f. output voltage of only 9.3 volts. This is a definite indication that at high r.f. input levels, a grid leak-condenser detector gives much lower a.f. output than does a C bias detector. (Table *51* shows an N.R.I. a.f. output value of 45 volts for a 9.6-volt r.f. input to the C bias detector.)

With 1-volt r.f. input to the grid leak-condenser detector for the last measurement, the N.R.I. a.f. output voltage in Table *53* is 12.3 volts, which is even higher than was obtained with 9 volts r.f. input. An analysis of the circuit will explain why lowering of the r.f. input gives higher a.f. output.

In the grid leak-condenser detector circuit of Fig. *8*, the C bias voltage is developed across grid leak-condenser combination R_8-C_7 by the flow of grid current through the grid circuit. Increased r.f. input to the detector thus *increases* the negative C bias voltage.

With extremely weak signals, the operating point of a grid leak-condenser detector stage is at the cut-off point of the grid voltage-grid current characteristic curve, where changes in applied grid voltage have a maximum

effect upon *grid* current. (When no input signal is present, some of the electrons emitted by the cathode will hit the grid and flow through the grid circuit to produce an initial negative bias.) At higher r.f. input signal levels, the increased negative C bias moves the operating point beyond grid current cut-off, so that increased r.f. input is counteracted by the increased negative C bias. This explains why a high r.f. input voltage may give even less a.f. output voltage than does a 1-volt r.f. input.

Your own a.f. output value obtained with 1-volt r.f. input may differ considerably from the N.R.I. value, however, depending upon the characteristics of your 6SJ7GT tube. You may even obtain slightly less a.f. output with 1-volt r.f. input than with high input.

	R.F. OUTPUT VOLTAGE IN VOLTS OF R.F. AMP. STAGE	R.F. INPUT VOLTAGE IN VOLTS TO DET. STAGE	MAXIMUM A.F. OUTPUT VOLTAGE IN VOLTS	A.F. OUTPUT VOLTAGE IN VOLTS FOR 1 V. R.F. INPUT
YOUR VALUE				
N.R.I. VALUE	30 x V 111	3 x V 9	3 x V 9.3	3 x V 12.3

TABLE 53. Record your results here for Experiment 53, in which you make voltage measurements in an r.f. amplifier stage and a grid leak-condenser detector stage.

The calculations in the preliminary discussion showed that a C bias detector gave only about 4.7 volts a.f. output for 1-volt r.f. input; this indicates definitely that the grid leak-condenser detector responds better than a C bias detector to *weak signals*. At input voltages lower than 1 volt, such as are commonly encountered when tuning a radio receiver to weak or distant stations, the superiority of the grid leak-condenser detector over the C bias detector would be even more evident.

With a C bias detector, the C bias is essentially constant, being determined by the flow of plate current and bleeder current through the cathode resistor (R_6 in Fig. *3*), and places the operating point near plate current cut-off, where small variations in r.f. input voltage have little effect upon *plate* current.

A grid leak-condenser detector designed for efficient weak-signal detection may cause distortion on strong signals. Reducing the value of the grid leak resistance will eliminate distortion at a sacrifice in weak-signal sensitivity, but the fidelity of a grid leak-condenser detector at high signal levels can never approach that of a diode detector or C bias detector.

Instructions for Report Statement No. 53. Technicians have found from experience that the grid condenser is a highly important part in a grid leak-condenser detector. First of all, it provides a low-reactance path for modulated r.f. signals to the grid of the detector tube, thereby applying maximum input signal voltage between the grid and cathode of this tube. Secondly, a grid condenser of proper capacity makes the voltage across the grid resistor follow the peaks of the r.f. grid current, thereby producing across this resistor the desired a.f. voltage. An open grid condenser is an entirely possible defect in a receiver, so for this report statement, let us introduce this defect and see what happens.

With your apparatus still set up as it was for the last measurement in Step 2 of this experiment (1 volt r.f. input directly to detector, and phone still in N.R.I. Tester), set the 250,000-ohm potentiometer on the experimental chassis for maximum a.f. output (maximum clockwise). Locate .0005-mfd. grid condenser C_7, unsolder its lead from terminal *4* of socket *Y*, and bend this lead so it will make contact with *4* when you press

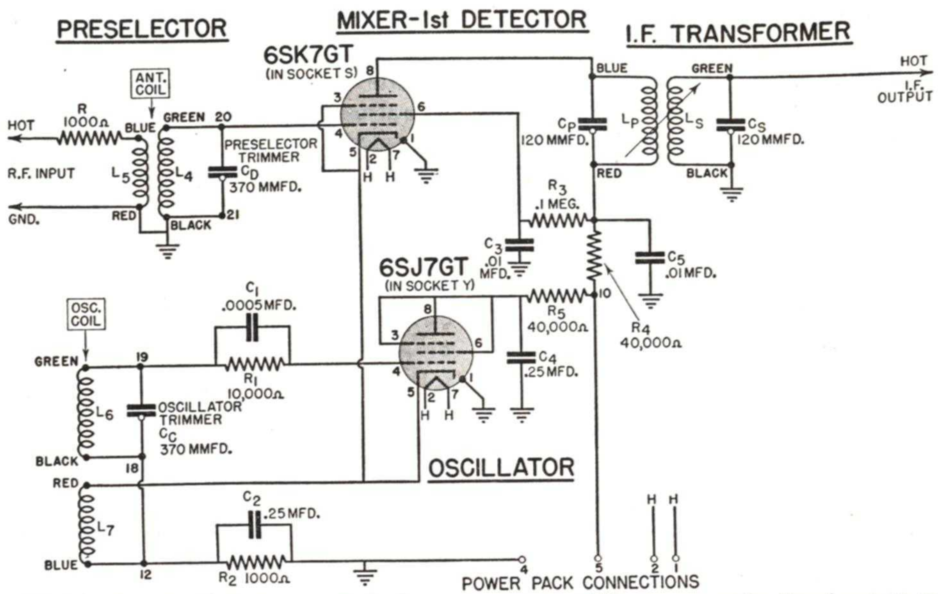


FIG. 9. Schematic circuit diagram of the frequency converter which you set up for Experiment 54 to demonstrate the basic principles of a superheterodyne receiver. Note that the 6SJ7GT pentode tube is here connected as a triode (with the screen grid and suppressor grid connected to the plate) for use in the oscillator stage. The arrow passing through the two i.f. transformer coil symbols indicates that the coupling between these coils is adjustable. The i.f. output voltage is obtained between the hot i.f. output lead and the chassis.

on the body of the condenser. Turn on all apparatus, note the meter reading (*3* × *V* range), and listen to the phone while the condenser lead is pressed against *4*, then open the grid condenser by allowing this lead to move away from *4*. Note the effect upon the meter reading and upon phone volume (try various voltage ranges as called for by the result obtained), then answer Report Statement No. 53.

EXPERIMENT 54

Purpose: **To set up a frequency converter which will demonstrate the principles of frequency conversion employed in superheterodyne radio receivers; to show that a tuned antenna transformer contributes r.f. gain; to show that a frequency converter contributes r.f. gain; to show the importance of proper alignment in a superheterodyne circuit.**

Preliminary Discussion: The schematic circuit diagram of the frequency converter which you will assemble for this experiment is given in Fig. *9*. The antenna coil supplied to you in Radio Kit 5RK is used as a tuned r.f. transformer in the preselector. In a commercial superheterodyne receiver, this preselector would amplify the desired incoming r.f. signal and reject interfering signals.

The 6SK7GT tube is used as a mixer-first detector tube, and is followed by an i.f. transformer which accepts the desired i.f. signal while rejecting other signals. The coils on your i.f. transformer are so mounted that the distance between them can be changed, thereby varying the coefficient of coupling and giving a choice either of peak or band-pass operation.

The oscillator stage is of the modified tuned grid type, and uses the type 6SJ7GT pentode tube connected as a triode, with the screen grid and suppressor grid being tied to the plate.

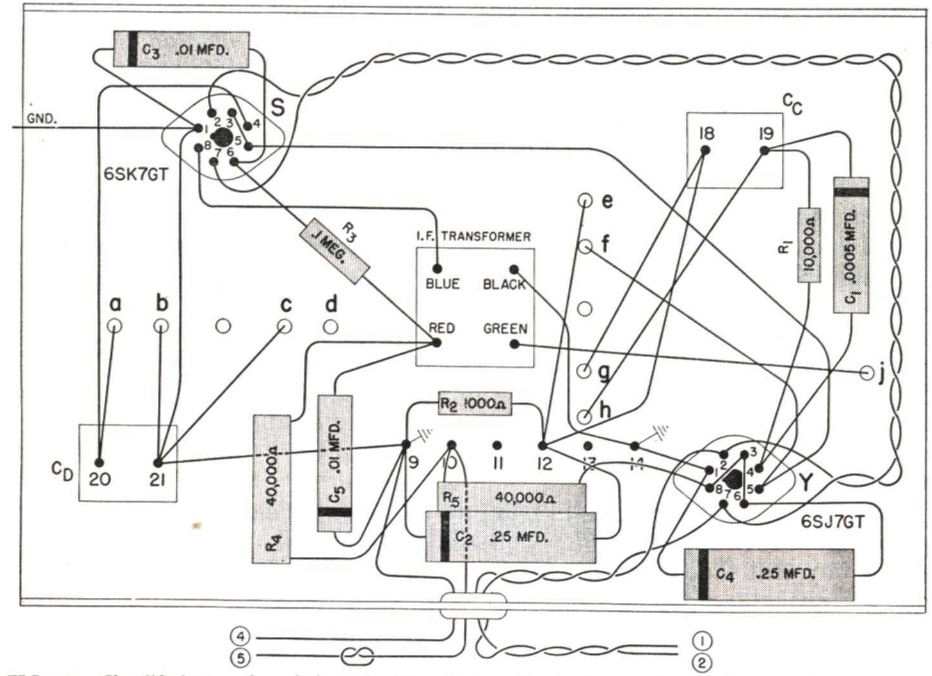


FIG. 10. Simplified type of semi-pictorial wiring diagram showing how under-chassis connections are made for the frequency converter circuit of Fig. *9*. Values and positions of parts are only approximate in a diagram of this type, for the diagram is merely intended to show the points between which various parts and leads are to be connected for best results. You are expected to use your own judgment more and more now as you progress with the experiments in this manual. Connections are indicated only by dots; *there are no connections at cross-overs* of circuit lines on this diagram.

The feed-back coil is connected to the cathode, but r.f. plate current flows through the coil just as if it were connected to the plate in the conventional manner. The .25-mfd. by-pass condenser (C_4) places the plate of the oscillator at ground potential for r.f., but both the cathode and the control grid are at fairly high r.f. potentials with respect to ground.

The plate and screen grid currents of the mixer-first detector tube and the plate current of the oscillator tube flow through 1000-ohm resistor R_2, developing across this resistor a d.c. voltage which serves as the negative C bias for the mixer-first detector tube. An automatic C bias for the oscillator tube is developed across grid resistor R_1 by the flow of rectified grid current.

The r.f. signal voltage developed across feed-back coil L_7 is introduced between the cathode of the mixer-first detector tube and ground, in series with the negative C bias voltage existing across R_2. Since the grid return of the mixer tube is also grounded, we have both an r.f. voltage and a negative C bias voltage applied to the control grid of the mixer-first detector tube, with the values of these voltages being correct for frequency conversion.

Step 1. To assemble on your experimental chassis a frequency converter having the circuit shown in Fig. 9, carry out the following steps carefully while using the simplified semi-pictorial wiring diagram in Fig. 10 and the photographic illustration in Fig. 11 as your guides.

a. Disconnect the experimental chassis from the signal generator, then disconnect the four power supply leads of the experimental chassis from the power pack output terminals.

b. Remove all leads both above and underneath the experimental chassis except the twisted filament leads on terminals *2* and *7* of sockets *S* and *Y* and the two power pack leads on terminals *9* and *10*. Remove the antenna coil and the 250,000-ohm potentiometer. You should now have left on the experimental chassis only the two tube sockets, the six-lug terminal strip, trimmer condenser C_O, trimmer condenser C_D, the four power supply leads and the twisted filament leads between sockets *S* and *Y*.

c. Mount the antenna coil on top of the chassis in holes *jj* and *pp*, in such a way that the terminal lugs are near chassis holes *a*, *b*, *c* and *d*.

d. Mount the oscillator coil (supplied to you in Radio Kit 6RK and used now for the first time) on top of the chassis in holes *hh* and *ii*, in such a way that its lugs are near holes *e*, *f*, *g* and *h*.

e. Mount the i.f. transformer (Part *6-6* having two trimmer condenser sections and two coils) underneath the chassis in hole *ff*, using the single mounting screw already on the unit, and rotating the entire transformer to a position whereby the red and green dots on the side of the ceramic base are next to the six-lug terminal strip. The red dot will now be near terminal *9* on the strip.

Identify the adjusting screws for the two trimmer condensers by placing the notation C_P on the top of the experimental chassis alongside hole *v* (see Fig. *4*) and placing the notation C_S alongside hole *w*, as shown in Fig. *11*. Use metal-marking crayon.

f. Connect *9* to *21*. Again you are expected to use your own judgment as to the best time for soldering each joint. Use the semi-pictorial wiring diagram as your guide whenever possible; thus, the diagram in Fig. *10* indicates that four wires are to be connected to *21*, so you would naturally wait until all four wires were placed on this terminal before soldering it.

g. Connect *21* to *black* of *Ant.* coil through *b*.

h. Connect *21* to *red* of *Ant.* coil through *c*.

i. Connect *21* to *1* of *S*. (Now is a logical time to solder *21*.)

j. Connect a 5-inch length of hook-up wire to *1* of *S*, to serve as the grounded r.f. input lead.

k. Connect *20* to *green* of *Ant.* coil through *a*.

l. Connect *20* to *4* of *S*.

m. Connect a .01-mfd. condenser between *1* and *6* of *S*.

n. Connect *8* of *S* to *blue* of i.f. transformer. (A blue dot on the side of the ceramic identifies this terminal.)

o. Connect *3* and *5* of *S*.

p. Connect *5* of *S* to *5* of *Y*.

q. Connect *1* of *Y* to *14*.

r. Connect together *3*, *6* and *8* of *Y*.

s. Connect a .25-mfd. condenser between *1* and *6* of *Y*, with the outside foil lead going to *1*, since this terminal is grounded.

t. Connect a 40,000-ohm resistor between *8* of *Y* and *10*.

u. Connect a 40,000-ohm resistor between *10* and *red* of i.f. transformer.

v. Connect a 100,000-ohm resistor between *6* of *S* and *red* of i.f. transformer.

w. Connect a .01-mfd. condenser between *9* and *red* of i.f. transformer, with the outside foil lead going to *9*.

x. Connect *14* to *black* of i.f. transformer.

y. Connect a 6-inch length of hook-up wire to *green* of i.f. transformer, and run this wire through hole *j* to serve as the hot i.f. output lead.

z. Connect *18* to *12*.

aa. Connect *18* to *black* of *OSC.* coil through *g*.

bb. Connect *19* to *green* of *OSC.* coil through *h*.

cc. Connect a 10,000-ohm resistor between *4* of *Y* and *19*.

dd. Connect a .0005-mfd. condenser between *4* of *Y* and *19* (the outside foil lead can go to either terminal since neither is grounded).

ee. Connect *5* of *Y* to *red* of *OSC.* coil through *f*.

ff. Connect *12* to *blue* of *OSC.* coil through *e*.

gg. Connect a 1000-ohm resistor between *9* and *12*.

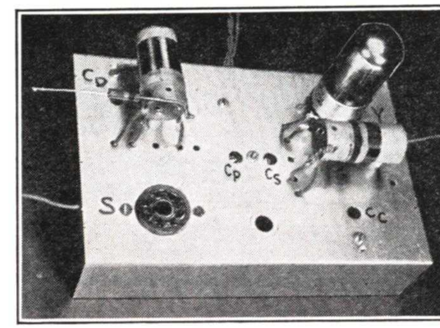


FIG. 11. Top view of the experimental chassis after the frequency converter has been completely wired. Note how the 1000-ohm resistor is attached to the *blue* terminal of the antenna coil and used as the hot r.f. input lead. The 6SK7GT tube was removed from socket *S* before taking this photograph, in order to show antenna coil connections more clearly.

hh. Connect a .25-mfd. condenser between *9* and *12* (outside foil lead going on *9*).

ii. Check all connections underneath the chassis carefully to be sure they correspond to the connections shown in Fig. *10*, then arrange all resistors and condensers so they are within the limits of the chassis but no leads are touching each other.

jj. Connect one lead of a 1000-ohm resistor to *blue* of *ANT.* coil, and allow this resistor to project out beyond the chassis as shown in Fig. *11* so that its other lead will serve as the hot r.f. input lead.

kk. Connect your signal generator output leads to the r.f. input leads of the frequency converter (knotted s.g. lead on the free lead of the 1000-ohm resistor, and grounded leads connected to each other).

ll. Connect the four power supply leads for the frequency converter to the power pack output terminals.

mm. Insert the type 6SK7GT tube in socket *S* on top of the experimental chassis, and insert the type 6SJ7GT tube in socket *Y*.

Step 2. To measure d.c. electrode voltages in your frequency converter, first reduce the r.f. output of the signal generator to zero by rotating the potentiometer on the s.g. chassis in a counter-clockwise direction as far as it will go. Prepare the N.R.I. Tester for d.c. voltage measurements.

Measure the d.c. plate voltage of the 6SK7GT mixer-first detector tube (red clip on the *red* terminal of the i.f. transformer, black clip on *12*). Record your result in Table *54* as the d.c. plate voltage in volts of the 6SK7GT tube. (The d.c. voltage applied to the plate of the tube is measured in this manner to prevent the r.f. voltages developed across primary winding L_P of the i.f. transformer and across feed-back winding L_7 of the oscillator coil from affecting the d.c. measurement. A measurement directly between the plate and cathode of the mixer-first detector tube would give a much higher reading, because the r.f. voltages produced by the oscillator stage would add to the d.c. voltage).

Even though instructions are not specifically given, you are expected to choose the proper voltage range for each measurement (using the *100* × *V* range first whenever in doubt), and d.c. control grid voltage in volts for the 6SK7GT tube.

Measure the d.c. plate voltage of the 6SJ7GT oscillator tube (red clip on *8* of *Y*, black clip on *12*). Record your result in Table *54* as the d.c. plate voltage in volts of the 6SJ7GT tube.

Measure the C bias voltage of the 6SJ7GT oscillator tube (red clip on *19*, black clip on *4* of *Y*). Do not touch either the test leads or the N.R.I. Tester chassis when making this measurement, for the capacity

NATURE OF MEASUREMENT IN STEP 2	6SK7GT TUBE		6SJ7GT TUBE	
	YOUR VALUE	N.R.I. VALUE	YOUR VALUE	N.R.I. VALUE
D.C. PLATE VOLTAGE IN VOLTS		200		48
D.C. SCREEN GRID VOLTAGE IN VOLTS		100		
D.C. CONTROL GRID VOLTAGE IN VOLTS		12.9		13.5

	R.F. VOLTAGE ACROSS PRESELECTOR RESONANT CIRCUIT	R.F. VOLTAGE ACROSS PRIMARY OF I.F. TRANSFORMER	R.F. VOLTAGE ACROSS SECONDARY OF I.F. TRANSFORMER	R.F. OUTPUT VOLTAGE OF OSCILLATOR IN VOLTS
YOUR VALUE				
N.R.I. VALUE	3.7	30 x V 132	30 x V 90	3 x V 5.4

TABLE 54. Record your results here for Experiment 54, in which you make voltage measurements in a frequency converter circuit.

wait for tubes to warm up each time. Turn off all apparatus before touching and moving the test clips, unless otherwise instructed.

Measure the d.c. screen grid voltage of the 6SK7GT mixer-first detector tube (red clip on *6* of *S*, black clip on *12*), and record your result in Table *54* as the d.c. screen grid voltage in volts for the 6SK7GT tube.

Measure the C bias voltage of the 6SK7GT mixer-first detector tube (red clip on *12*, black clip on chassis). Record your result in Table *54* as the and resistance of your body may upset this automatic C bias voltage. Record your result in Table *54* as the d.c. control grid voltage in volts for the 6SJ7GT tube.

Step 3. To align the i.f. transformer to 480 kc., proceed as follows:

a. Set the two coils on the i.f. transformer ¾-inch apart, as shown in Fig. *12* (so that distance *D* in Fig. *13* is ¾-inch). Be careful not to break the coil leads or exert excessive force on the coils when changing their spacing.

b. Adjust all five trimmer condensers for maximum capacity by rotating the adjusting screw of each one clockwise as far as it will go (s.g. trimmer C_A; oscillator trimmer C_C; preselector trimmer C_D; i.f. primary trimmer C_P; i.f. secondary trimmer C_S).

c. Set s.g. trimmer C_A a slight amount (less than one-eighth turn) counter-clockwise.

d. Set preselector trimmer condenser C_D a slight amount counter-clockwise, the same as C_A.

e. Set oscillator trimmer C_C two complete turns counter-clockwise, so tion of the meter pointer, then adjust C_P for a maximum meter reading. Once a visual indication on the meter is obtained, the headphone is no longer needed; it can be left in the *PHONE* jacks or removed, as you prefer. Switch to a higher voltage range as soon as the pointer reaches *4.5* on the *AC* scale.

i. Adjust i.f. secondary trimmer C_S for a maximum meter reading. Readjust C_P and C_S alternately several times until you secure the highest possible meter reading (you will very likely be using the *30* × *V* range).

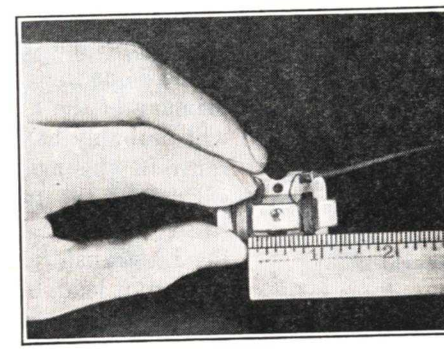


FIG. 12. Method of adjusting the spacing between the i.f. coils for a particular coupling value. Measurements are always made between the inside edges of the coils, thereby measuring the spacing between the coils. It is usually best to have the coils approximately the same distance from center of the supporting wood rod, but this is not essential to satisfactory operation. The coils will slide readily along the wood supporting rod.

it will not interfere with i.f. alignment.

f. Set the 1000-ohm potentiometer on the s.g. chassis to a mid-position, so that the movable arm is opposite and in line with the center terminal of the potentiometer.

g. Place the red clip on the hot i.f. output lead, place the black clip on the chassis, and prepare the N.R.I. Tester for listening to audio signals (selector switch at *V*). Now turn on the power pack and the N.R.I. Tester.

h. Rotate i.f. primary trimmer C_P counter-clockwise until you hear a tone in the phone and note a deflec-

This procedure aligns the i.f. transformer approximately to 480 kc.

Step 4. To align the oscillator and preselector trimmers of your frequency converter for reception of a 780-kc. signal, proceed as follows:

a. Set s.g. trimmer condenser C_A one complete turn counter-clockwise, to 780 kc.

Note: Whenever instructions for resetting a trimmer condenser are given, first return to the maximum-capacity position by rotating clockwise as far as possible, then rotate counter-clockwise the specified number of turns for the new setting.

b. Set preselector trimmer C_D one complete turn counter-clockwise, to 780 kc.

c. With all apparatus still turned on, switch to the *V* range. In Step 3e, oscillator trimmer C_C was set two turns off; starting from this setting, rotate oscillator trimmer C_C *clockwise* slowly while watching the meter, until you note a meter deflection. Adjust carefully for maximum output, switching to the higher voltage ranges as necessary. This sets the oscillator trimmer to 1260 kc., which is 480 kc. (the i.f. value) above the s.g. frequency of 780 kc.

d. Readjust preselector trimmer C_D for maximum output.

e. Readjust i.f. trimmers C_P and C_S alternately several times for maximum output. You have now completed alignment of your frequency converter for reception of the 780-kc. modulated r.f. signal being produced by the signal generator.

Step 5. To make r.f. voltage measurements under dynamic (operating) conditions in your frequency converter, first connect the N.R.I. Tester to measure the r.f. input of the frequency converter, by placing the red clip on the hot (knotted) input lead and placing the black clip on the chassis (*V* range, headphone removed). Turn on all apparatus, wait a minute, then adjust the s.g. potentiometer to give an r.f. input voltage of exactly 1 volt. (Be sure the tester zero calibration is accurate.) Do not change the setting of this potentiometer or of C_A for the remainder of this experiment.

Connect the N.R.I. Tester to measure the r.f. voltage at the input of the mixer-first detector (red clip on *green* terminal of *ANT.* coil, black clip on chassis, *V* range), turn on all apparatus, adjust preselector trimmer C_D for a maximum meter reading to offset the detuning effect of the N.R.I. Tester, then read the meter and record your result in Table *54* as the r.f. voltage across the preselector resonant circuit.

Connect the tester to measure the r.f. voltage across the primary of the i.f. transformer (red clip on *8* of *S*, black clip on chassis), arrange the connection to *8* so you can set the chassis upright without having the clip short to other terminals, then turn on your apparatus, adjust preselector trimmer C_D for maximum meter reading, then adjust i.f. trimmer C_P for maximum meter reading. Read the meter now, and record your result in Table *54* as the r.f. voltage across the primary of the i.f. transformer. You will probably have to use the *30* $\times$ *V* range for this measurement.

Connect the tester to measure the r.f. voltage across the secondary of the i.f. transformer (red clip on hot i.f. output lead, black clip on chassis), and adjust trimmer condensers C_P and C_S for maximum meter readings. Record your maximum result in Table *54* as the r.f. voltage across the secondary of the i.f. transformer.

Measure the r.f. output voltage of the oscillator (red clip on *5* of *Y*, black clip on chassis), and record your result in Table *54*. Do not adjust any trimmer condensers for this measurement.

Discussion: The N.R.I. values recorded in Table *54* for the d.c. electrode voltages of the 6SK7GT mixer-first detector tube indicate that we are using normal voltages such as you will encounter in this stage in a superheterodyne receiver. Thus, the plate voltage is 200 volts, and the screen grid voltage is half the plate voltage. The C bias is 12.9 volts, which likewise is normal for the mixer-first detector stage because it gives an operating point which is near plate current cut-off.

This C bias is developed across resistor R_2 by the flow of mixer and oscillator plate current and mixer screen grid current, and is applied to the control grid of the 6SK7GT tube in series with whatever r.f. voltage is developed across coil L_7 by the oscillator circuit.

The N.R.I. values given in Table *54* for the 6SJ7GT oscillator tube indicate a plate voltage of 48 volts. We measured this voltage between plate terminal *8* and terminal *12* (Fig. *9*) in order to eliminate from this d.c. voltage measurement the r.f. voltage across winding L_7 of the oscillator coil. (The .25-mfd. plate by-pass condenser, C_4, places terminal *8* at r.f. ground potential, and the .25-mfd. condenser C_2 places terminal *12* at r.f. ground potential. Measuring between points which are at ground potential for r.f. signals eliminates r.f. while giving an essentially correct d.c. voltage measurement, for the d.c. voltage drop across coil L_7 is negligibly small.)

The N.R.I. grid bias value of 13.5 volts for the oscillator tube is developed across 10,000-ohm grid resistor R_1 by the flow of the rectified grid current, and is near the bias value commonly encountered in triode oscillators.

The plate supply resistors (R_4 and R_5) for both tubes have the same ohmic value of 40,000 ohms, but the oscillator draws more plate current through its resistor and hence has a lower d.c. plate voltage.

All r.f. voltage measurements for Step 5 are made with the modulated signal generator set for an r.f. output of 1 volt, but this r.f. input voltage of 1 volt is applied to winding L_5 of the antenna coil through 1000-ohm resistor *R* to prevent L_5 from loading the signal generator excessively. Winding L_5 has an impedance of approximately 250 ohms at the s.g. frequency, so we have a 1250-ohm voltage divider in which the useful r.f. input voltage developed across coil L_5 is one-fifth of the applied 1-volt r.f. input, or .2 volt ($250 \div 1250 = 1/5$).

The N.R.I. value obtained across preselector trimmer C_D was 3.7 volts r.f.; dividing this by the r.f. input voltage of .2 volt gives approximately 19 as the resonant voltage step-up of this preselector circuit. This high resonant step-up is obtained because the grid circuit of the mixer-first detector tube places only a negligible load upon this resonant circuit.

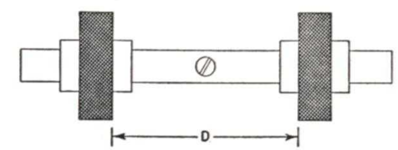


FIG. 13. Measure the distance *D* when adjusting the i.f. coils to a definite coupling value as specified in the instructions.

Conversion Gain. If we divide the r.f. voltage value obtained across the plate load of the mixer-first detector by the r.f. input voltage to this stage, we obtain a value which is commonly known as the *conversion gain* of the frequency converter. The N.R.I. value obtained across the plate load (across the primary of the i.f. transformer) was 132 volts r.f., dividing this by the r.f. input voltage of 3.7 volts gives a conversion gain of about 36; this is entirely normal for a frequency converter.

An N.R.I. value of only 90 volts (less than the primary voltage) was obtained across the secondary of the i.f. transformer, but again the condition is normal. A double-tuned i.f. transformer in a superheterodyne radio receiver cannot provide voltage step-up, and power losses in the secondary winding cause a slight loss in voltage.

The N.R.I. value of r.f. voltage fed into the grid circuit of the mixer-first detector stage by the local oscillator is 5.4 volts; this is higher than the 3.7-volt modulated r.f. signal input to the grid circuit, and is about one-half the C bias voltage on the mixer grid. This relationship between voltages is typical of a mixer stage employing grid injection of the oscillator signal; with plate or screen grid injection, much higher r.f. voltages would be required from the local oscillator stage. The grid includes all parts connected between the grid and cathode, hence we have grid injection when we introduce the oscillator signal anywhere in the grid circuit, such as in the cathode lead.

Alignment. The most important part of the alignment procedure for a frequency converter is the adjustment of the local oscillator trimmer (C_C in Fig. *9*), for this adjustment sets the beat frequency to the desired i.f. value. Adjustment of the i.f. transformer trimmers to resonance then brings the gain up rapidly. The two i.f. trimmers must be readjusted alternately several times, for there is some interaction between the primary and secondary tuned circuits.

Alignment is completed by adjusting preselector trimmer condenser C_D; this has no effect upon frequency, but does insure a maximum modulated r.f. input to the mixer stage. When complete alignment was obtained in the N.R.I. laboratory, an input voltage of approximately .2 volt was boosted to an i.f. voltage of 90 volts across the secondary of the i.f. transformer, thus giving for the preselector and frequency converter system a voltage gain of 90 divided by .2, or approximately 450.

A typical i.f. amplifier stage can readily provide a gain of about 100; thus, we could obtain a total voltage gain of 45,000 by feeding the frequency converter output signal into an i.f. stage (450 × 100 = 45,000). When you assemble a complete superheterodyne circuit in a later experiment, you will actually approach this voltage gain.

Instructions for Report Statement No. 54. If the local oscillator stage in a superheterodyne receiver should fail for any reason whatsoever, the effect upon receiver performance will be quite definite. You undoubtedly know already what to expect when this trouble occurs, but for this report statement you will actually stop the local oscillator and see for yourself what happens.

Connect the N.R.I. Tester to measure the r.f. voltage across the secondary of the i.f. transformer by placing the red clip on the hot i.f. output lead coming out of chassis hole *j*, and placing the black clip on the chassis. The selector switch should be at *30* × *V*.

Turn on all apparatus, while leaving the settings of the various controls exactly as they were after you completed the alignment procedure in the last step of this experiment. Allow about a minute for the parts to reach normal operating condition, then stop the local oscillator by shorting temporarily the feed-back coil L_7 while watching the meter. You can do this simply by holding a screwdriver blade against the *red* and *blue* terminals of the oscillator coil.

Having made this test, you should have no difficulty now in answering Report Statement No. 54.

EXPERIMENT 55

Purpose: **To demonstrate how both the selectivity and the output voltage of an i.f. transformer vary with the amount of coupling between the i.f. coils.**

Step 1. To check the alignment of your frequency converter when connected according to the circuit of Fig. 9, proceed as follows:

Connect the N.R.I. Tester to measure the i.f. output voltage across the secondary of the i.f. transformer (red clip on the hot i.f. output lead, black clip on chassis, selector switch at *30* × *V*).

Set the s.g. potentiometer at its mid-position, and check the setting of s.g. trimmer C_A to make certain it is still at 780 kc. (one turn counter-clockwise from its maximum-capacity position). The space between the i.f. coils (distance *D* in Fig. *13*) should still be ¾ inch.

Turn on all apparatus, and adjust oscillator trimmer C_C for maximum output.

Adjust preselector trimmer C_D for maximum output.

Adjust i.f. primary trimmer C_P for maximum output.

Adjust i.f. secondary trimmer C_S for maximum output.

If you cannot secure alignment with this procedure, the i.f. transformer is probably out of alignment; realign it to 480 kc. according to the instructions given in Step 3 of Experiment 54, then realign the entire frequency converter according to the instructions in Step 4 of Experiment 54. The s.g. is now producing a 780-kc. signal for the next step, and the frequency converter is tuned for reception of this signal.

Step 2. To measure the i.f. output voltage for five different i.f. transformer coupling values, first adjust the s.g. potentiometer to give 12 volts r.f. across the secondary of the i.f. transformer. (Use the *3* × *V* range, adjust the s.g. potentiometer to get 12 volts r.f. with red clip on hot i.f. lead, black clip on chassis, readjust C_P and C_S for maximum output to compensate for the tester capacity, then readjust the potentiometer to give exactly 12 volts r.f. output.) This will allow you to use the *3* × *V* range for all measurements in this experiment. Do not touch the signal generator for the remainder of the experiment.

The coupling will be specified in terms of the separation between the two coils of the i.f. transformer. Since you now have an i.f. output voltage of 12 volts for a ¾-inch coupling, record 12 as the i.f. output voltage in volts for a coupling of ¾ inch in Table *55*. Now rotate C_S a small amount (about ⅛ turn) in either direction from the maximum output setting, and note how far down the meter pointer swings. Assume this degree of swing to be medium tuning, and record *MED.* in the ¾-inch box under "NATURE OF TUNING" in Table *55*. After making each of the other measurements called for in this experiment, vary C_S in this same manner; if the pointer drops farther (changes more rapidly) than it did for the ¾-inch coupling, record the tuning as *SHARP;* if there is less change, record the tuning as *BROAD*.

Set the i.f. transformer coils ⅞ inch apart, adjust i.f. trimmers C_P and C_S in turn for maximum output and record your result as the i.f. output voltage for a coupling of ⅞ inch.

Set the i.f. coils 1⅛ inches apart, readjust C_P and C_S for maximum output, and record your result as the i.f. output voltage for a coupling of 1⅛ inches.

Set the i.f. coils ⅝ inch apart, readjust C_P and C_S for maximum output, and record your result in Table *55* as the i.f. output voltage for a coupling of ⅝ inch.

Set the i.f. coils ⅜ inch apart, readjust C_P and C_S for maximum output, and record your result in Table *55* as the i.f. output voltage for a coupling of ⅜ inch.

Discussion: Examination of the N.R.I. values in Table *55* shows that weak coupling (maximum spacing of 1⅛ inches) gives sharp tuning and the lowest i.f. output voltage. Additional separation of coils would make the i.f. output voltage drop considerably more. The highest i.f. output voltage is obtained for a coupling value about midway between minimum and maximum coupling. Furthermore, as coupling is increased by moving the coils closer together, the i.f. trimmer adjustments become less critical; we say that tuning becomes broader.

The three curves in Fig. *14* show in a graphical manner how the degree of coupling affects the characteristics of an i.f. transformer. The curve for weak coupling is narrow and sharp, indicating that small changes in the capacity of either i.f. trimmer condenser will cause quite large changes in i.f. output voltage; in other words, tuning is sharp and highly critical.

The curve for optimum coupling in Fig. *14* shows that we get considerably higher i.f. output voltage with this coupling than with weak coupling. Furthermore, the adjustments are less critical, so that considerable change in capacity is required to lower the i.f. output voltage appreciably.

The curve for over-coupling in Fig. *14* corresponds to the maximum coupling of ⅜ inch employed in this experiment. Although more i.f. output voltage is obtained with over-coupling than with weak coupling, circuit adjustments are now very broad, so that a slight change in an i.f. trimmer setting has little effect upon the i.f. output voltage.

DISTANCE D IN INCHES BETWEEN I.F. COILS	I.F. OUTPUT VOLTAGE IN VOLTS		NATURE OF TUNING	
	YOUR VALUE	N.R.I.	YOUR VALUE	N.R.I.
1⅛		7.2		SHARP
⅞		11.1		MED.
¾		12.0		MED.
⅝		11.4		BROAD
⅜		11.1		BROAD

TABLE 55. Record your results here for Experiment 55, in which you measure the output voltage of your frequency converter while using various coupling values in the i.f. transformer.

You were instructed to retune the i.f. trimmer condensers each time you changed the degree of coupling. This retuning is necessary because one tuned circuit in the i.f. transformer reflects its reactive characteristics into the other tuned circuit, with the amount of reflection being dependent upon the amount of coupling. A change in coupling thus detunes

slightly both the primary and secondary resonant circuits of the i.f. transformer. By retuning for peak output, we correct this condition.

As we increase the coupling by moving the coils closer together, two actions occur: The increased mutual inductance between the coils gives a greater induced voltage in the secondary winding, and the loading effect of the secondary circuit upon the primary circuit increases. These two effects oppose each other, so that the i.f. output voltage across the secondary is low for both weak and maximum coupling values, but is a maximum for an optimum in-between coupling.

The Q factor of each tuned circuit

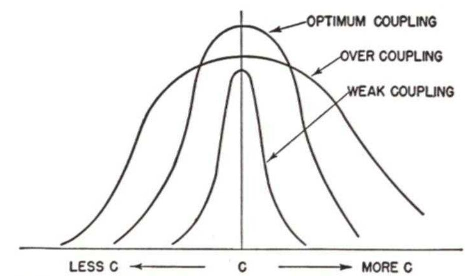


FIG. 14. Frequency response curves of your i.f. transformer for three different coupling values.

in an i.f. transformer has a definite effect upon the optimum coupling; the lower the Q factor of each resonant circuit (both are identical), the greater must be the coupling to give the optimum condition of maximum i.f. output voltage. (Actually, the coefficient of coupling which gives the optimum condition can be computed by dividing the number 1 by the Q factor of either resonant circuit.)

As coupling is increased, the losses in the tuned circuits have more and more interaction upon each other, with the result that the Q factor of each circuit drops. A lower Q factor means broader tuning.

In this experiment, we adjusted the i.f. transformer for peak output. Oftentimes, however, the two tuned circuits are left slightly off resonance in opposite directions, so as to secure a double-peaked resonant characteristic which is desirable when wide bands of frequencies are to be passed. This type of i.f. transformer adjustment is known as a band-pass adjustment. Voltage gain must be sacrificed when a band-pass characteristic is desired.

Instructions for Report Statement No. 55. In the i.f. transformer which you will encounter in your work as a Radiotrician, it is entirely possible that there will be one or more shorted turns in either of the windings. Shorted turns in an i.f. transformer winding have two distinct effects upon the operation of a superheterodyne receiver; they detune the i.f. transformer, causing lowered output volume and possibly even distortion, and they increase resonant circuit losses, so that after retuning, the output of the receiver is still considerably lower than normal.

For this report statement, you will introduce a shorted turn in your i.f. transformer, and see for yourself how this common i.f. transformer defect affects the output voltage of the i.f. transformer.

Cut a 2½-inch length of red hookup wire, push the insulation back from each end for about 1/8 inch, bend the wire into a circle with the bare ends overlapping about 1/16 inch, then solder the ends together by means of a lap joint. Push the insulation back now so as to cover this joint as much as possible. You now have a single shorted turn of wire.

Set the i.f. coils ¾ inch apart, adjust C_P and C_S in turn for maximum i.f. output, and readjust the s.g. potentiometer if necessary in order to secure exactly 12 volts i.f. output.

Place your shorted turn of wire over the secondary coil of the i.f. transformer (this is the right-hand coil, connected to the *black* and *green* terminals) in the manner shown in Fig. *15*, and record the meter reading in the margin of this page. Now retune i.f. trimmer condensers C_P and C_S for maximum output, record the new meter reading, then compare your two measured voltage values with the 12-volt i.f. output obtained without the shorted turn, and answer Report Statement No. 55. Use the $3 \times V$ range throughout this extra test.

EXPERIMENT 56

Purpose: **To demonstrate three types of interference trouble commonly encountered in superheterodyne receivers: *1.* Code interference, which occurs when an undesired carrier signal having a frequency equal to the i.f. value of the receiver gets through the preselector; *2.* Image interference, which occurs when an undesired carrier signal which is above the desired signal frequency by twice the i.f. value gets through the preselector; *3.* Beat note interference, which occurs when an undesired signal which differs from the desired signal by an audio frequency value gets through the preselector.**

Preliminary Discussion of Code Interference. Radiotricians commonly encounter the complaint that a radiotelegraph code station is heard on a superheterodyne receiver at all broadcast band settings, with the interference being more severe at the low-frequency end of the band. The trouble is generally due to the fact that the signal from a code station located in the vicinity and having a carrier frequency equal to the i.f. value of the receiver is getting through the preselector, even though the preselector is tuned far off from this interfering signal frequency. The mixer-first detector stage in the receiver acts as a class B amplifier in amplifying this signal and feeding it into the i.f. amplifier. Since this undesired code signal has a carrier frequency corresponding to the i.f. value of the receiver, it passes through the i.f. amplifier along with the desired i.f. signal, and is demodulated in the second detector along with the desired signal. The code signal is consequently heard along with the desired program.

Code interference can also occur when the frequency of the interfering code station is some fraction of the i.f. value of the receiver, for the mixer-first detector stage produces strong harmonics when acting as an amplifier, and one of these harmonics will then be equal to the i.f. value of the receiver. Thus, if the i.f. value is 450 kc., a code station operating on a carrier frequency of 225 kc. would produce code interference because its second harmonic (450 kc.) corresponds to the i.f. value.

The reason this type of interference is known as code interference is simply that the interfering stations are Government and commercial radiotelegraph stations using the International Morse Code for communication purposes. These stations operate on frequencies ranging from about 20 kc. to about 540 kc., and the i.f. values commonly used in superheterodyne receivers are within this range.

Code interference can occur only if the preselector of the superheterodyne receiver is broad enough in its tuning characteristics to pass the undesired signal along with that to which the preselector and other tuned circuits in the receiver are tuned. Code interference can be remedied either by inserting in the antenna circuit a wave trap which will reject the signals from the interfering station or by changing the i.f. value of the receiver enough to prevent the interfering code signal from passing through the i.f. amplifier.

Code interference is reduced by tuning the receiver away from the frequency of the interfering station, and consequently code interference is seldom serious at the high-frequency end of the broadcast band. Tuning the preselector closer to the interfering frequency will make the interference increase.

To demonstrate a condition equivalent to code interference in this experiment, we will first tune the frequency converter for reception of a broadcast band frequency being produced by the signal generator. Next, we will reset the modulated signal generator to a lower frequency corresponding to a code station frequency which could produce code interference in an actual receiver, and see if we can hear this signal when using the N.R.I. Tester as an aural indicator connected to the i.f. output. Now, if we tune the preselector to this interfering frequency, the signal should increase in volume. Furthermore, pulling out the oscillator tube should have no appreciable effect upon the interfering signal since it is riding right through the mixer-first detector stage without undergoing frequency conversion.

Trimmer Condenser Settings. In the apparatus which you now have set up, consisting of a modulated signal generator and a frequency converter, there are five trimmer condensers. In order to demonstrate interference troubles with this apparatus, it is necessary that you know how to set each of these trimmers to a particular desired frequency within its range.

The trimmer condensers and the coils which make up our five tuning circuits are manufactured with sufficient uniformity to make possible the table given in Fig. *16*, in which is specified for each trimmer condenser the approximate frequency in kilocycles corresponding to various settings of the adjusting screw. In this table, the maximum-capacity setting, corresponding to rotation of the adjusting screw as far as it will go in a

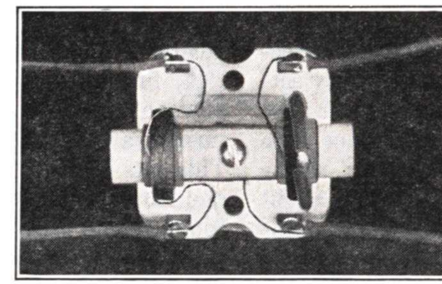


FIG. 15. Place a soldered loop of hook-up wire over the secondary winding of the i.f. transformer in the manner shown here, when you are ready to duplicate the effect of a shorted turn in an i.f. coil according to the instructions given for the special tests in connection with Report Statement No. 55.

NUMBER OF TURNS OFF FROM MAXIMUM CAPACITY POSITION	0	1/4	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2	2 1/2	3
SIGNAL GENERATOR TRIMMER C_A	450	600	680	740	780	820	870	920	960	1080	1200
PRESELECTOR TRIMMER C_D	450	600	680	740	780	820	870	920	960	1080	1200
OSCILLATOR TRIMMER C_C	720	970	1100	1200	1260	1320	1380	1490	1600	1840	1960
I.F. TRIMMERS C_P AND C_S	340	430	530	600	710	760	820	850	920	990	1100

Fig. 16. This chart gives you the *approximate* frequency in kilocycles corresponding to various settings of each of the five trimmer condensers used in Experiment 56. We cannot specify the exact frequency you will get for a particular adjustment as this depends on the distributed capacity of your circuit wiring and the actual value of capacity and inductance for a given trimmer and coil. Remember, coils and variable condensers are made only to within certain limits of the rated value just like resistors and fixed condensers, and you have to allow for these normal variations.

clockwise direction, is designated as zero turns. The horizontal row across the top gives the number of turns of rotation in a *counter-clockwise* direction from this maximum-capacity setting. Use this chart whenever you are instructed to set a trimmer to a particular frequency. Never rotate a trimmer condenser more than about three turns in a counter-clockwise direction from its maximum-capacity position, for additional counter-clockwise rotation will loosen the adjusting screw, and you may find it difficult to replace the screw without jamming its threads.

Step 1. To demonstrate how code interference can occur in a superheterodyne receiver, first make sure that the signal generator and the frequency converter are still properly connected to each other and to the power pack, with all tubes in position. The i.f. coils should still be 3/4 inch apart. The shorting loop used in the report statement test for Experiment 55 should be removed.

Connect the N.R.I. Tester to the i.f. output for aural indications (red clip on hot i.f. output lead, black clip on chassis, selector switch at *V*, headphones in *PHONE* jacks). Set all five trimmer condensers to maximum capacity.

To align your apparatus for reception of a 920-kc. signal being produced by the signal generator, as indicated in the block diagram in Fig. *17A*, first rotate the adjusting screw of each i.f. trimmer (C_P and C_S) 3/4 turn in a counter-clockwise direction. This sets each i.f. trimmer to 600 kc., and therefore gives your frequency converter an i.f. value of 600 kc.

Set your signal generator to produce a carrier frequency of 920 kc., by rotating s.g. trimmer C_A 1 3/4 turns counter-clockwise. Set the s.g. potentiometer to a mid-position.

Tune your frequency converter to the 920-kc. output of the signal generator in the following manner:

Rotate oscillator trimmer C_C 3 complete turns counter-clockwise as a preliminary adjustment.

Set preselector trimmer C_D to 920 kc. by rotating it 1 3/4 turns counter-clockwise.

With all apparatus turned on, rotate oscillator trimmer C_C slowly clockwise while listening to the headphone and watching the meter. Note the condenser settings at which you hear the loudest tones and secure maximum meter readings. Continue rotating clockwise until you reach the maximum-capacity position, then go back in a counter-clockwise direction

to the position which gave the highest meter reading, and adjust C_C carefully now for maximum output. Switch to higher voltage ranges whenever necessary.

The oscillator is set at about 1520 kc., which is the correct frequency for conversion of the desired 920-kc. signal to the i.f. value of 600 kc. (920 kc. plus the i.f. value of 600 kc. gives 1520 kc.).

Adjust preselector trimmer C_D for maximum output, using the meter as your guide. Meter indications are

Your frequency converter is now aligned for normal superheterodyne operation with an i.f. value of approximately 600 kc., and with the preselector and oscillator tuned to receive the 920-kc. tone-modulated signal being produced by the s.g., as indicated by the block diagram in Fig. *17A*. You should be able to hear the audio modulation with the headphone.

To demonstrate code interference, set s.g. trimmer C_A to 600 kc. (the i.f. value) by rotating it 1/4 turn counter-clockwise from the maximum-capacity

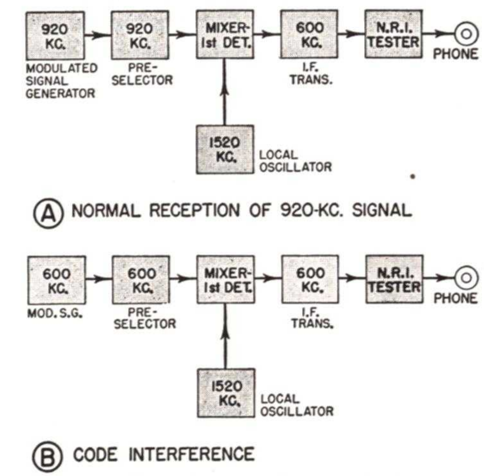


FIG. 17. Block diagrams indicating the frequency to which you tune each section of your apparatus in order to demonstrate code interference in Step 1 of Experiment 56.

more satisfactory than the headphone for final alignment, but you can leave the headphone plugged into the tester during alignment since accurate voltage values are not required.

Adjust i.f. primary trimmer C_P for maximum output.

Adjust i.f. secondary trimmer C_S for maximum output. You will have to rotate the adjusting screw of C_S counter-clockwise quite a bit (reduce its capacity) in order to compensate for the tester capacity connected across C_S. Readjust C_P for maximum output.

setting. The meter pointer will probably drop to zero, so switch to the *V* range and listen to the headphone. The signal will be extremely weak or not heard at all, for the preselector is still tuned to 920 kc. and consequently offers considerable rejection to the 600-kc. interfering signal now being produced by the s.g.

Without turning off any apparatus, tune the preselector to 600 kc. by rotating preselector trimmer C_D slowly clockwise until the audio tone is loudest. C_D should now be about 1/4 turn counter-clockwise from its maximum setting. You now have the conditions represented by the block diagram in Fig. *17B*, and should be able to hear an audio tone in the phone and note a meter deflection. Readjust trimmer C_A for maximum output. Readjust preselector trimmer C_D for maximum output. You have now shown that an interfering signal having a frequency corresponding to the i.f. value increases in strength as the preselector is tuned *toward* the interfering frequency.

To prove that the interfering 600-kc. signal is riding through the mixer-first detector independently of the local oscillator, remove the 6SJ7GT oscillator tube from socket *Y* while leaving the apparatus on and leaving all settings as they were. The signal strength as indicated by the meter should remain essentially the same, and the audio tone should remain strong. Any difference in loudness and meter reading is due to the changes which occur in electrode voltages of the mixer-first detector tube while the oscillator tube is removed.

Replace the oscillator tube in its socket, then turn off all apparatus.

Step 2. To demonstrate image interference in a superheterodyne circuit, first study the following preliminary discussion of this subject.

One condition for reception of a desired signal by a superheterodyne circuit is that the frequency of the local oscillator shall differ from the frequency of the desired signal by the *i.f. value*. In other words, if the i.f. value is 450 kc. and the desired signal frequency is 900 kc., the local oscillator must be either at 1350 kc. or 450 kc. to give reception of the desired 900-kc. signal. Usually, the oscillator in a superheterodyne receiver is tuned to the *higher* of the two possible frequencies (1350 kc. in this example), for interference problems become more serious when the oscillator is tuned to the lower frequency.

Whenever the oscillator in a superheterodyne circuit is set to some definite frequency, any signal which differs from this oscillator frequency by the i.f. value will produce a new signal capable of passing through the i.f. system. For example, with the oscillator set at 1350 kc. and with an i.f. value of 450 kc., either the desired 900-kc. signal or an undesired 1800-kc. signal at the input of the mixer will produce a 450-kc. signal which can pass through the i.f. amplifier. The undesired signal frequency is called the *image frequency,* and is always *above the desired signal frequency by twice the i.f. value of the receiver* in an ordinary superheterodyne receiver where the oscillator operates *above* the incoming signal frequency.

Image interference can be eliminated only with a preselector. A highly selective preselector which is tuned to the desired signal frequency will reject the undesired image frequency, for there is considerable difference between the frequencies of the desired and undesired signals.

To demonstrate image interference, we will first tune our entire superheterodyne circuit for normal reception of a 900-kc. modulated r.f. signal being produced by the signal generator. The i.f. value will be adjusted to 450 kc. This means that the local oscillator will now be at 1350 kc. The block diagram corresponding to this condition is given in Fig. *18A*.

The image frequency for the superheterodyne circuit condition represented by Fig. *18A* is 1350 plus 450, or 1800 kc. Your signal generator will not produce a frequency as high as this, so we will set it to 600 kc. and utilize the third harmonic as the interfering image signal. Naturally,

this 1800-kc. third harmonic is quite weak in comparison with the strength of the fundamental 900-kc. signal; in order to get sufficient signal strength at the grid of the mixer-first detector stage, we will temporarily remove the preselector circuit, thereby giving the set-up shown in Fig. *18B*.

To make an actual demonstration of image interference, first change the i.f. value of your circuit to 450 kc. (as called for in Fig. *18A*), in the following manner: With tester and s.g. connections the same as in the previous step, turn on all apparatus; set the s.g. potentiometer for maximum output; set s.g. trimmer C_A to 450 kc. (zero turns); set preselector trimmer C_D to 450 kc. (zero turns); set oscillator trimmer C_O three turns counterclockwise so the oscillator will not interfere with i.f. alignment; set i.f. trimmers C_P and C_S to 450 kc. (about ¼ turn off); adjust i.f. trimmers C_P and C_S carefully for maximum output as indicated by the meter.

Having aligned the i.f. transformer to 450 kc., adjust as follows to secure normal reception of a 900-kc. signal, as represented by the block diagram in Fig. *18A*: Set s.g. trimmer C_A to 900 kc. (approximately 1⅝ turns, as indicated in Fig. *16*); set preselector trimmer C_D to 900 kc.; set oscillator trimmer C_O to 1350 kc.; adjust oscillator trimmer C_O for maximum output; adjust preselector trimmer C_D for maximum output. You may hear a squeal in the phone (along with the audio tone of the s.g.) as you tune C_O to the maximum-output setting.

To remove the preselector from your frequency converter circuit, turn off the apparatus, unsolder the knotted s.g. output lead from the 1000-ohm resistor lead, unsolder from terminal *20* underneath the experimental chassis the lead which goes to *4* of socket *S,* then connect this unsoldered lead temporarily to the knotted s.g. output lead. Set s.g. trimmer C_A to 450 kc.

With the N.R.I. Tester still connected across the i.f. transformer secondary, using the *V* range and the headphone in the *PHONE* jacks, turn on all apparatus and listen to the phone. You should be able to hear an audio tone, for the s.g. is now set at the i.f. value, and its signal rides right through the mixer-first detector and the i.f. transformer. To verify this, pull out the oscillator tube (the 6SJ7GT tube in socket *Y*) while listening to the tone in the phone; the tone should still come through, with only a slight change in its volume (removal of one tube changes d.c. electrode voltages on the other tubes slightly). Replace the oscillator tube.

Now rotate s.g. trimmer C_A slowly

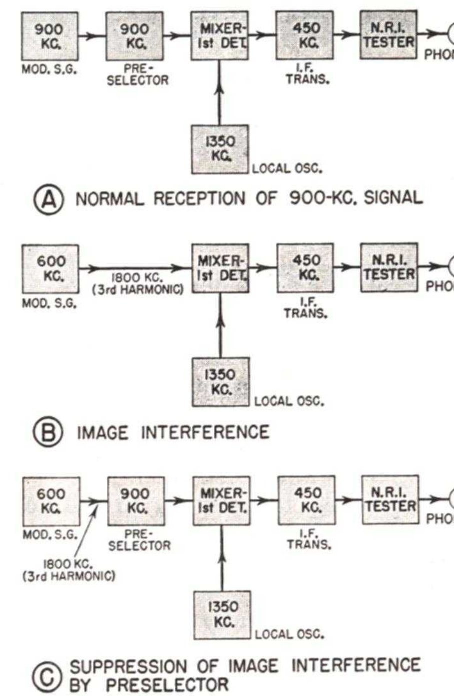


FIG. 18. Block diagrams indicating (in the boxes) the frequency to which each section of your apparatus is tuned for the image interference demonstration in Step 2 of Experiment 56.

counter-clockwise, so as to increase the s.g. frequency. At about ¼ turn, corresponding to 600 kc., you should hear faintly the image signal, which is produced by the 1800-kc. third harmonic of the s.g. beating with the 1350-kc. local oscillator signal (1800 — 1350 = 450, the i.f. value). You now have conditions corresponding to Fig. *18B*.

Continue rotating s.g. trimmer C_A slowly counter-clockwise to a position about 1⅝ turns off, corresponding to an s.g. frequency of about 900 kc. A strong audio tone and squeal should now be heard, for you now have normal reception of a 900-kc. signal, along with a squeal produced by interaction between the 1350-kc. local oscillator signal and the 1800-kc. fourth harmonic of the i.f. signal.

You may hear faint signal tones or squeals at intermediate positions, due to interaction between various harmonics of the s.g., local oscillator and i.f. signals, but for the present you can neglect these.

Retune s.g. trimmer C_A to 600 kc. (¼ turn off), so as to employ the third harmonic of 600 kc. as the image signal again. Now adjust i.f. trimmer C_S carefully for maximum audio tone output, in preparation for the next test.

To demonstrate how the preselector keeps back an image signal, reconnect the preselector into your circuit by returning the knotted s.g. output lead to the free lead of the 1000-ohm resistor and restoring the connection between *20* and *4* of *S* underneath the experimental chassis, while leaving preselector trimmer C_D still set to 900 kc. as it was. You now have conditions corresponding to Fig. *18C*, and the tone due to the image signal should be very weak or not heard at all. Adjusting s.g. trimmer C_A slightly in either direction to make sure it is exactly on 600 kc. should not restore the tone.

An i.f. value of 456 kc. has become standard for practically all superheterodyne entertainment receivers today. The reason for this is simply that with broadcast stations operating on frequencies which are multiples of 10 kc., harmonics of this i.f. value cannot produce squeals due to beating with the local oscillator signal when a station is tuned in.

To demonstrate for yourself that squeals are absent when the i.f. value is increased to 456 kc., rotate i.f. trimmers C_P and C_S each a slight amount (less than ⅛ turn) counter-clockwise so as to give an i.f. value of approximately 456 kc. Next, set s.g. trimmer C_A to 900 kc., so this can serve as the desired incoming signal. Readjust oscillator trimmer C_O for maximum signal output now by rotating it slightly counter-clockwise; you should now hear the audio tone in the phone without a squeal, and no squeal should be heard when you rotate the oscillator trimmer slightly in either direction to duplicate the tuning in of a station on a conventional receiver.

(Computations which explain why the squeal is not heard are as follows: With a 456-kc. i.f. and a 900-kc. incoming signal, the local oscillator would be set at 900 plus 456, or 1356 kc. The second harmonic of the i.f. signal would be 456 times 2, or 912 kc. This 912-kc. signal beats with the 1356-kc. signal to give a 444-kc. undesired signal; even though this is close enough to the i.f. so that it might ride through, the difference between 444 and 456 is 12 kc., or 12,000 cycles, which is too high to be heard as an audio squeal.)

At this time, make the extra report statement test according to the instructions given at the end of this experiment, then answer Report Statement No. 56. When this is done, come back to Step 3, which is an optional experiment.

Step 3. To demonstrate intermodulation interference, first study the following preliminary discussion carefully.

Whenever two carrier signals which differ by the i.f. value enter the preselector of a superheterodyne circuit, with the local oscillator being tuned for reception of one of these signals, the frequency converter will mix the desired and local oscillator signals to produce the desired i.f. signal, and will also mix the desired and undesired incoming signals to produce an undesired i.f. signal. These two i.f. signals will pass through the i.f. system and be mixed together in the second detector of the superheterodyne receiver. If these i.f. signals differ slightly in frequency (due either to slight detuning of the local oscillator or to the fact that the incoming interfering signal is *not exactly* above or below the desired signal by the i.f. value), they will be mixed together in the second detector, and an audio frequency tone equal to the difference in the i.f. signal frequencies will be fed into the a.f. amplifier and reproduced by the loudspeaker as a squeal which is heard along with the programs of either or both stations.

If the undesired input carrier signal is a harmonic of a code station employing a keyed carrier, the interference will be in the form of a coded tone heard along with the desired broadcast program.

Since a demonstration of intermodulation interference is possible only if there is a broadcast station below about 1060 kc. in your locality, Step 3 is presented here only as an optional experiment; try it out, but do not spend too much time on it if first results are unsatisfactory.

First of all, realign the i.f. trimmers to 450 kc. (set C_A to 450 kc., set C_D to 450 kc., set C_P and C_S to 450 kc., then adjust C_P and C_S for maximum output). Leave the s.g. potentiometer full clockwise (for maximum r.f. output) throughout this entire step.

For convenience, let us designate

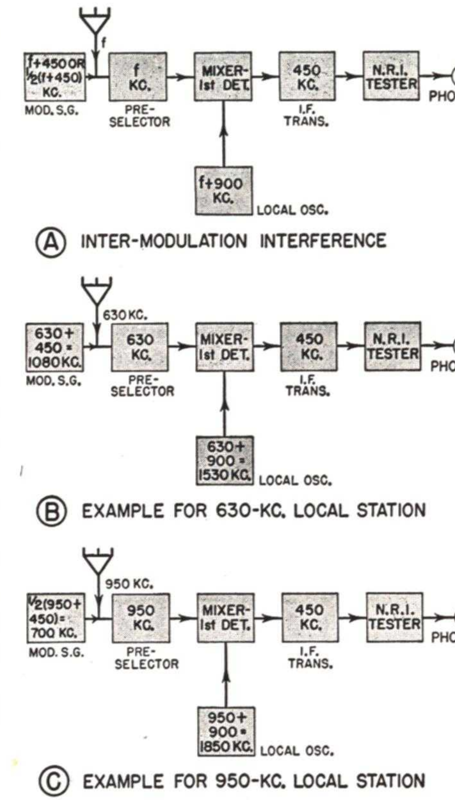


FIG. 19. Block diagrams indicating the frequency to which each section of your apparatus is tuned for the optional demonstration of inter-modulation interference in Step 3 of Experiment 56. In each case, *f* is the frequency of a local station below about 1060 kc.

the frequency of your local station as *f*. Using the frequency chart in Fig. *16* as your guide, adjust preselector trimmer C_D to *f*; adjust oscillator trimmer C_C to $f + 900$, and adjust s.g. trimmer C_A to $f + 450$, so as to secure the conditions of Fig. *19A*. If $f + 450$ is higher than 1200 kc. (the highest obtainable s.g. frequency), tune C_A to one-half of $f + 450$, so you will be using the second harmonic of the s.g. as the required $f + 450$ signal for this demonstration.

For local stations between 540 kc. and 750 kc., you can use the fundamental of the s.g., as illustrated for a 630-kc. local station in Fig. *19B*. For local stations between 750 kc. and 1060 kc., you will have to use the second harmonic of the s.g., as illustrated for a 950-kc. station in Fig. *19C*.

Connect your 50 to 100-foot long outdoor antenna to the *blue* terminal of the *ANT*. coil. Remove the local oscillator tube (6SJ7GT) from socket *Y*, and adjust s.g. trimmer C_A until the local station is heard in the phone along with the audio tone of the s.g. Set preselector trimmer C_D to the frequency of the local broadcast station, and adjust for maximum volume of the local-station program. Now replace the oscillator tube in socket Y, and adjust oscillator trimmer C_C for maximum volume of the tone produced by the s.g. As this adjustment is made, you should hear the characteristic squeal of intermodulation interference along with the tone of the s.g. and the program of the local station.

Discussion: You have now demonstrated all three types of interference specified in the purpose of this experiment, and have verified the importance of the preselector in minimizing interference.

You may also hear a faint squeal in Step 2 as you tune C_A to the 600-kc. setting, for the fourth harmonic of the desired i.f. signal is 1800 kc. ($450 \times 4 = 1800$), and this 1800-kc. harmonic beats with the 1350-kc. local oscillator signal to produce a beat frequency corresponding approximately to the i.f. value. We now have two i.f. signals riding through the i.f. transformer, one being slightly off 450 kc. whenever the s.g. signal is slightly detuned from 600 kc. In the detector stage (in the N.R.I. Tester), these two i.f. signals are mixed together, so that their difference in frequency is heard in the phone as an audio squeal along with the desired audio tone modulation.

Instructions for Report Statement No. 56. When the announcers and performers at a broadcast station studio are silent for a few seconds, such as between programs, no sounds come from the loudspeakers of receivers tuned to that station. Many people think that the station itself is off the air during this interval, but radio men realize that only the modulation is stopped. The station is radiating the carrier signal, and the receiver is still amplifying this signal and feeding it into the second detector. Only the audio amplifier section of the receiver and the loudspeaker are temporarily inactive.

You can readily demonstrate that the carrier signal is present even though modulation is removed, by tuning your entire frequency converter for normal reception of the signal to which you set the s.g. in the last step of this experiment, then temporarily removing the modulation from the signal generator and noting the effect upon the i.f. output voltage as indicated by the meter of the N.R.I. Tester.

With all apparatus still connected and adjusted for the last test in Step 2 (normal reception of a 900-kc. signal from the s.g. while using an i.f. value of 456 kc.), remove the audio tone modulation from the r.f. output of the signal generator by shorting together the *G* and *F* terminals of the audio transformer on the s.g. chassis temporarily with your screwdriver. Do this several times while listening to the headphone unit and watching

the meter, then answer Report Statement No. 56.

Return now to Step 3 of this experiment, and perform it if local conditions permit.

EXPERIMENT 57

Purpose: **To assemble on your experimental chassis an a.v.c.-controlled tuned r.f. amplifier stage followed by a diode detector which produces an a.v.c. voltage; to show that a.v.c. reduces the r.f. input to the detector; to demonstrate the time delay action of an R-C filter.**

You have now progressed sufficiently with your practical radio training to be able to assemble this circuit by following the schematic diagram in Fig. *20*, without the aid of semi-pictorial diagrams. The experience you obtain from this assembly project will prove extremely valuable in later radio work. Here are some suggestions:

You should now have on the experimental chassis the following parts: Tube sockets *S* and *Y*, trimmer condenser C_D, the i.f. transformer, the antenna coil, the 6-lug terminal strip, twisted leads connecting terminals *2*

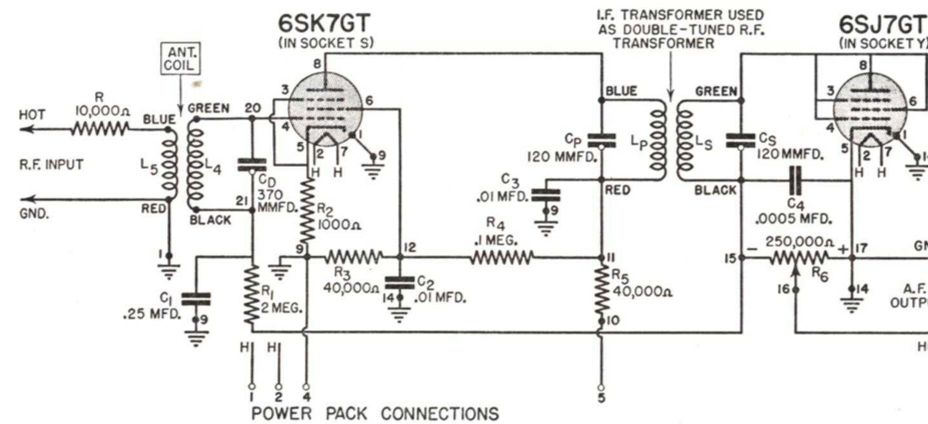


FIG. 20. Schematic circuit diagram of the tuned r.f. amplifier stage and diode-detector stage which you assemble in Step 1 of Experiment 57. Terminal numbers on this diagram correspond to those which you previously placed on your own experimental chassis.

Step 1. To assemble on your experimental chassis the r.f. amplifier-detector circuit of Fig. 20, disconnect from the power pack the four power supply leads for the experimental chassis, and disconnect the experimental chassis from the signal generator.

Remove the type 6SJ7GT and 6SK7GT tubes, then remove all leads and small parts (resistors and condensers) both on top of and underneath the experimental chassis, *except the twisted filament leads and the four power supply leads.* Remove also the oscillator coil and oscillator trimmer C_C.

and *7* of the two tube sockets, and four power supply leads going out through the rubber grommet. Lettering on top of and underneath the chassis should correspond to that shown in Fig. *10*; if any letters have been smeared, wipe them off with a piece of cloth and reletter neatly with metal-marking crayon.

Mount 250,000-ohm potentiometer R_6 in hole *t*, with the three terminal lugs next to the i.f. transformer.

Starting at the r.f. input and working methodically toward the a.f. output, wire up your apparatus according to the schematic in Fig. *20*. If a question arises regarding placement of a resistor or condenser, reference to the top and bottom views of the completed units (Figs. *21* and *22*) may help. For your convenience, grounding and anchoring terminals have been marked on Fig. *20*.

The free lead of the 10,000-ohm resistor (*R*) which you connect to *blue* of the *ANT.* coil will serve as the hot r.f. input lead. A 4-inch length of wire connected to *1* of *S* will serve as the grounded r.f. input lead.

A 7-inch lead on *16*, brought up through hole *i*, will serve as the hot a.f. output lead; place a knot in this lead. A 7-inch lead on *5* of *Y*, brought up through hole *j*, will serve as the grounded a.f. output lead.

Chances for errors or omissions in wiring can be minimized by drawing another schematic diagram in the following manner as you wire up the unit: First draw all of the schematic symbols in their proper positions (tube, coil, resistor and condenser symbols), and number all terminals exactly as indicated in Fig. *20*. Now begin the wiring; each time you complete a connection, draw that corresponding line on your diagram. When you have finished, check your diagram against Fig. *20* to see if you have omitted any connections.

Adjust resistor and condenser leads so the parts are within chassis limits but not shorting (see Figs. *21* and *22*). Now connect the four power supply leads to the power pack, connect the r.f. input to the s.g. output (knotted s.g. lead on free lead of *R*, and grounded s.g. lead to grounded r.f. input lead), insert the 6SK7GT tube in socket *S*, and insert the 6SJ7GT tube in socket *Y*.

Step 2. To calibrate the s.g. potentiometer in terms of r.f. output voltage, first remove the audio modulation from the signal generator and increase the r.f. output of the s.g. by making these changes underneath the *signal generator chassis:* Remove the 18,000-ohm resistor which is connected between terminals *1* and *8* of the tube socket under the s.g. chassis.

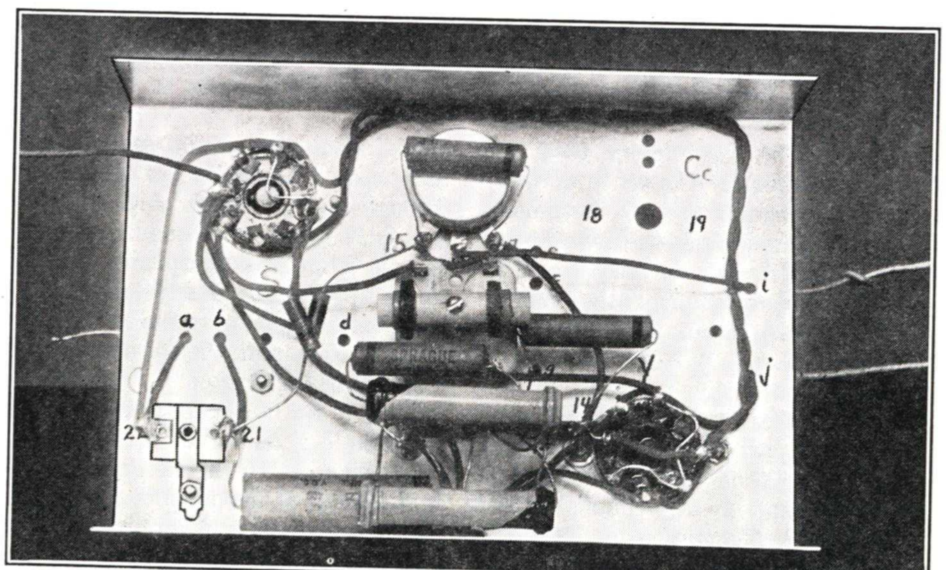


FIG. 21. Bottom view of the experimental chassis, showing how it should appear after wiring of the tuned r.f. amplifier and diode detector has been completed according to the instructions given in Step 1 of Experiment 57.

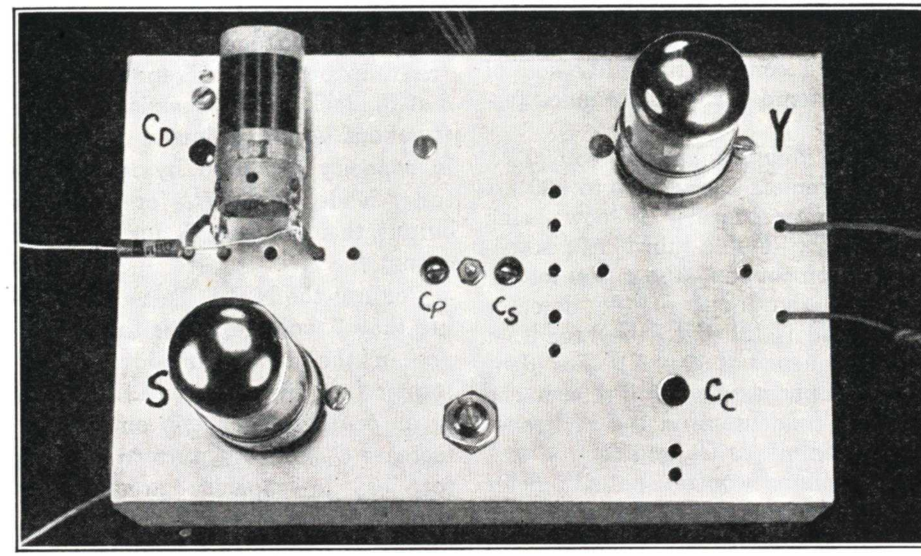


FIG. 22. Top view of the experimental chassis as it should appear after you complete the assembly of the tuned r.f. amplifier and diode detector for Experiment 57.

Connect this 18,000-ohm resistor between terminals *11* and *12* of the s.g. chassis instead, so it is in parallel with the 40,000-ohm plate supply resistor already between these s.g. terminals.

Now carry out the following procedure:

Set s.g. trimmer C_A to 600 kc. (refer to Fig. *16* for the correct setting).

Set the s.g. potentiometer for maximum r.f. output (full clockwise).

Connect the N.R.I. Tester to measure its r.f. output (red clip on knotted s.g. lead, black clip on either chassis, selector switch at *V*, U-shaped jumper in *PHONE* jacks), then turn on all apparatus to check the operation of the signal generator. A reading somewhere around 3 volts r.f. indicates that the s.g. is operating satisfactorily.

To calibrate the s.g. potentiometer so you will be able to set it at various r.f. voltage values without having to measure the s.g. output, rotate the s.g. potentiometer shaft as far as it will go in a counter-clockwise direction, and mark the left-hand end of the slot in the shaft with your metal-marking crayon somewhat as indicated in Fig. *23*, so that you can use this end of the slot as an indicator. Mark a short line on the chassis for this slot position, and label it *0*, as in Fig. *23*.

Adjust the s.g. potentiometer until the s.g. is delivering an r.f. output voltage of exactly 1 volt, draw a line on the s.g. chassis corresponding to this slot position, and label it *1.0*; in the same manner, set the s.g. potentiometer in turn for *1.5* volts, *2* volts, *2.5* volts, *3* volts, etc., until you reach the limit of the signal generator, and mark each setting on the chassis as indicated for N.R.I. values in Fig. *23*. Since the maximum r.f. output voltage we could obtain was about *3.7* volts, the last marking was made at *3.5* volts.

Step 3. To tune and align your r.f. amplifier stage for reception of a 600-kc. signal, leave s.g. trimmer C_A set at 600 kc., adjust the s.g. potentiometer to a mid-position (to about 2 volts), then proceed as follows:

To remove a.v.c. action during

alignment, ground terminal *21* to the chassis by connecting a 6-inch wire to *21*, and connect the other end of this wire temporarily to grounded terminal *9*.

Set r.f. input trimmer C_D to 600 kc.

Set trimmers C_P and C_S to 600 kc. (The i.f. transformer is now being used as a double-tuned r.f. transformer for coupling the r.f. amplifier stage to the input of the detector stage, and is tuned to the broadcast band frequency of 600 kc.) For identification purposes, we will refer to the trimmer condensers on the i.f. transformer simply as C_P and C_S.

Set volume control potentiometer R_6 (on the experimental chassis) for maximum a.f. output voltage by ro-

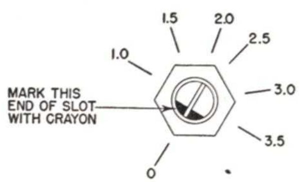


FIG. 23. Method of calibrating the potentiometer on the signal generator chassis so that you can later set this potentiometer to give a definite r.f. output voltage without the necessity of making a voltage measurement at the signal generator output.

tating clockwise as far as it will go (this connects *16* to *15*).

Remember that you are now expected to turn on the N.R.I. Tester and the power pack and choose correct tester ranges as required by the nature of each experiment, even though specific instructions are not given. Whenever in doubt, refer to the "OPERATING INSTRUCTIONS FOR N.R.I. TESTER" given in previous manuals.

Connect the N.R.I. Tester to measure the r.f. voltage across the r.f. input resonant circuit (red clip on *green* of *ANT*. coil, black clip on chassis), and adjust r.f. input trimmer C_D for maximum output.

Connect the N.R.I. Tester to measure the r.f. voltage across the primary of the double-tuned r.f. transformer (red clip on *blue* i.f. terminal or on *8* of *S*, black clip on chassis), increase C_D about ¼ turn to make up for loss in capacity produced by removal of tester leads, adjust C_P for maximum output, then readjust C_D for maximum output.

Connect the N.R.I. Tester to measure the r.f. voltage across the secondary of the double-tuned r.f. transformer (red clip on *green* i.f. terminal or on *6* of *Y*, black clip on chassis), increase C_P about ¼ turn to make up for loss in capacity produced by removal of tester leads, adjust C_S for maximum output, then readjust C_P for maximum output.

Connect the N.R.I. Tester to measure the D.C. VOLTAGE between the a.f. output leads (red clip on grounded a.f. output lead or chassis, black clip on hot (knotted) a.f. output lead), then adjust C_S, C_P and C_D in turn for maximum d.c. output voltage readings. You have now aligned all trimmers for a 600-kc. signal. (Note that we measure the *d.c.* voltage here.)

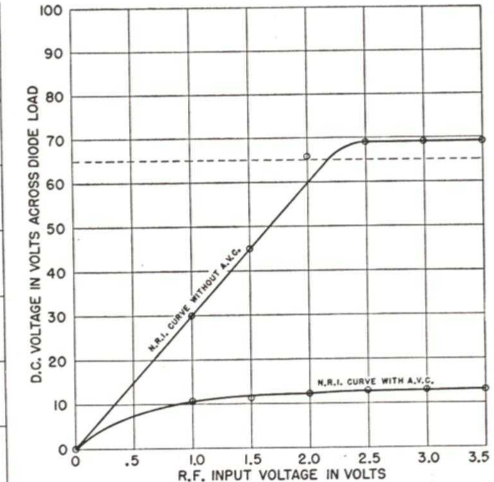
Step 4. To determine how a.v.c. action affects circuit voltages, first introduce a.v.c. action by unsoldering from *9* the 6-inch lead which runs to *21*. Allow this wire to project through the open end of the chassis, so you can use it again for shorting out temporarily the a.v.c. voltage.

Connect the N.R.I. Tester to measure the D.C. output VOLTAGE developed across 250,000-ohm diode load potentiometer R_6 (red clip on grounded a.f. output lead, black clip on hot a.f. output lead). Set this potentiometer for maximum a.f. output by rotating full clockwise.

Set the s.g. output to zero (s.g. po-

R.F. INPUT VOLTAGE IN VOLTS TO R.F. STAGE	D.C. OUTPUT VOLTAGE IN VOLTS ACROSS R6 WITH A.V.C. (TERM. 21 UNGROUNDED)		D.C. OUTPUT VOLTAGE IN VOLTS ACROSS R6 WITHOUT A.V.C. (TERM. 21 GROUNDED)	
	YOUR VALUE	N.R.I.	YOUR VALUE	N.R.I.
0		1.0		1.0
1		10.5		30
1.5		11.4		45
2.0		12		66
2.5		12.6		69
3.0		12.6		69
3.5		12.6		69

TABLE 57. Record your results here for Experiment 57, in which you make voltage measurements in a tuned r.f. amplifier stage followed by a diode detector, with and without a.v.c.



GRAPH 57. Plot on this graph the values which you obtained while performing Experiment 57, to secure two curves comparable to the N.R.I. curves already on this graph. Note that the N.R.I. curves do not pass through all points; instead, they are drawn as smooth curves passing as close as possible to the various points. This is common practice when preparing graphs, for the curve then averages out variations and inaccuracies in measured values.

tentiometer maximum counter-clockwise, at *0*). Turn on the apparatus. Move the experimental chassis at least four inches away from the s.g. chassis, adjust the position of the experimental chassis (by rotating it) for a ***minimum*** meter reading, then record your result in Table *57* as the d.c. output voltage *with a.v.c.* for zero volts r.f. input. (The chassis position adjustment reduces to a minimum the direct radiation of r.f. energy from the *S.G.* coil to the *ANT*. coil, so that r.f. input to the 6SK7GT tube will be controlled by the s.g. potentiometer.)

Now ground terminal *21* so as to remove the a.v.c. voltage, by holding against the experimental chassis the free end of the lead which you attached to *21*. Read the d.c. voltage indicated by the meter for this condition, and record your result in Table *57* as the d.c. output voltage *without a.v.c.* for zero r.f. input.

Set the s.g. potentiometer for 1 volt r.f., measure the d.c. output voltage with a.v.c. (terminal *21* ungrounded), and without a.v.c. (terminal *21* grounded), and record your results in Table *57*. In the same manner, measure and record d.c. output voltages with and without a.v.c. for r.f. input voltages of 1.5 volts, 2 volts, 2.5 volts, 3 volts, and 3.5 volts (if possible).

Now plot your results on Graph *57* so as to secure two curves, one with a.v.c. and one without a.v.c., corresponding to the N.R.I. curves already on this graph. In plotting, assume that the d.c. output voltage is zero both with and without a.v.c. when the r.f. input voltage is zero. The 1-volt N.R.I. value recorded in each case in Table *57* for zero r.f. input volts is due to conduction current in the diode detector, and will be explained later.

Step 5. To observe the time delay action of an a.v.c. filter while using the same circuit and meter connections as in Step 4, set the s.g. potentiometer for maximum output voltage, ground terminal *21* to the chassis so as to remove a.v.c. action, wait until the meter pointer comes to rest while using a suitable d.c. voltage range, then introduce a.v.c. action by ungrounding terminal *21*, and note how rapidly the meter pointer drops to a lower value. You will probably say that the change in meter pointer position is almost instantaneous.

Now disconnect 2-megohm a.v.c. filter resistor R_1, and connect in its place between terminals *15* and *21* a 10-megohm resistor. Again ground terminal *21* and let the meter pointer come to rest, then remove the grounding lead while watching the meter pointer. Notice how much more slowly the meter pointer drops when the ohmic value of the a.v.c. filter resistor is increased in this manner.

Discussion: First of all, let us analyze the schematic circuit diagram in Fig. *20*, so as to become thoroughly familiar with the circuit used in this experiment.

In this circuit, the antenna coil couples the grid circuit of the r.f. tube to the signal source. The 10,000-ohm resistor R in series with primary winding L_5 prevents this winding from loading the s.g., and also reduces the r.f. input to the grid of the 6SK7GT r.f. tube to more satisfactory values for these experiments. Trimmer condenser C_D tunes secondary winding L_4 to resonance at the desired signal frequency of 600 kc., so that maximum r.f. voltage is developed across this condenser for application to the control grid and cathode terminals of the 6SK7GT r.f. tube.

When terminal *21* is grounded to remove a.v.c. action, the input r.f. voltage is applied directly to the grid and cathode through 1000-ohm cathode resistor R_2. With terminal *21* ungrounded, the a.v.c. voltage developed across 250,000-ohm diode load resistor R_6 is also applied to the grid; the a.v.c. voltage then adds to the fixed C bias developed across cathode resistor R_2, making the control grid of the r.f. tube more negative than before. R_1 and C_1 form an a.v.c. filter which, in an actual receiver, would serve two purposes: filtering a.f. components which may exist across diode load R_6, and introducing a time delay action in the a.v.c. circuit.

The plate load for the r.f. tube is resonant circuit C_P-L_P, also tuned to 600 kc. since we are using a tuned r.f. amplifier circuit. R.f. current in L_P induces an r.f. voltage in L_S, and this produces across 600-kc. tuned circuit L_S-C_S an r.f. voltage which is applied to the diode-connected 6SJ7GT tube. (All three grids of this tube are connected to the plate to give diode operation.)

Diode plate current flows through 250,000-ohm diode load potentiometer R_6, developing across this load a d.c. voltage having the indicated polarity (so that *15* is negative with respect to the chassis). If the input signal is modulated, the a.f. modulation will also exist across potentiometer R_6, and any desired portion of the total available a.f. voltage can be obtained by adjusting this potentiometer.

The plate of the 6SK7GT r.f. tube receives its voltage through a 40,000-ohm plate supply resistor, R_5, which reduces the power pack output voltage to the normal plate voltage value for this tube. The screen grid voltage is reduced still more by means of a voltage divider consisting of 40,000-ohm resistor R_3 and .1-megohm resistor R_4, connected between *11* and the chassis. Condensers C_3 and C_2 serve as r.f. by-pass condensers for the plate and screen grid respectively of the r.f. tube, while C_4 serves to by-pass r.f. signals which would otherwise pass through the diode load resistor.

Grounding terminal *21* to remove a.v.c. action connects this terminal directly to the chassis end of 1000-ohm cathode resistor R_2. This also grounds terminal *15* through 2-megohm resistor R_1, thereby placing this 2-megohm resistor across R_6, but the ohmic value is so high that R_1 has negligible loading effect upon R_6.

With the normal s.g. circuit employed up to this time, the maximum obtainable r.f. voltage was only slightly more than 2 volts. Since at least 3 volts is required to secure a satisfactory calibration of the s.g. potentiometer, we had to boost the output voltage by increasing the plate-voltage on the s.g. tube. Audio modulation was not needed for this experiment, so we removed the 18,000-ohm cathode resistor (thus breaking the audio portion of the circuit) and placed this resistor in parallel with the 40,000-ohm plate supply resistor for the tube. This reduced the ohmic value of the plate supply resistance, thus increasing the plate voltage.

Whenever the N.R.I. Tester is connected across a resonant circuit, the tester capacity detunes the resonant circuit slightly. This is why you are instructed to retune each time you make a resonant circuit measurement. After the tester is removed, the trimmer condenser must be restored to its original setting, which explains why you are asked to readjust several trimmers each time you move the N.R.I. Tester to a different stage.

An analysis of the two N.R.I. curves in Graph *57* will serve as an example for you in analyzing your own results.

Consider first the N.R.I. curve *without a.v.c.* It is essentially linear up to about 65 volts d.c., corresponding to about 2 volts r.f. input. This is to be expected, for you proved in a previous experiment that *the d.c. voltage across a diode detector load is proportional to the r.f. voltage fed into the detector circuit* (corresponding to a linear curve).

At r.f. input voltages above 2 volts, however, the d.c. output voltage no longer increases linearly with the r.f. input to the r.f. amplifier stage. This means that the r.f. input voltage to the detector is no longer proportional to the r.f. input to the r.f. amplifier stage. The dash-dash horizontal line in Graph *57* represents the limit of linear operation. Actually, somewhere around an r.f. input of 2.5 volts we reached the condition whereby additional increases in r.f. input to the r.f. amplifier stage had no effect upon the d.c. output voltage.

Without a.v.c., high r.f. input voltages swing the r.f. amplifier tube grid positive on peaks, with the result that grid current flows and the grid circuit loads input resonant circuit L_4-C_D. In a radio receiver without a.v.c., or in a receiver in which the a.v.c. system is grounded by a short in the a.v.c. filter condenser (C_1 in Fig. *20*), this grid current flow might cause serious distortion when strong signals, such as from powerful local broadcast stations, were tuned in.

The N.R.I. curve labeled *"WITH A.V.C."* in Graph *57* shows that a.v.c. makes it possible to receive without distortion signals way above the 2-volt limit which existed without a.v.c. The a.v.c. system makes the C bias of the r.f. amplifier stage go up as input signal strength goes up, thereby preventing overloading and distortion.

When there are a number of r.f. stages in a receiver and each is a.v.c.-controlled, the a.v.c. action will be better, so that extremely strong r.f. input signals can be tuned in without distortion.

Automatic volume control reduces the strength of weak input signals as well as strong signals, but the reduction in gain for weak signals is very much less than for strong signals. This is a highly desirable condition for weak-signal reception. With delayed automatic volume control circuits, full amplification is provided for weak signals, and a.v.c. action begins cutting down signal strength only when signals exceed a certain value.

With a constant percentage of modulation, the a.f. output voltage developed across diode load resistor R_6 will be proportional to the r.f. input voltage for the diode detector stage, since the strength of the modulation signal always varies with the strength of its carrier signal. This means that the d.c. voltage measured across a diode load like R_C is proportional to the *a.f. output voltage* which would be obtained in a radio receiver.

When a.v.c. filter resistor R_1 is 2 megohms and C_1 is .25 mfd., as indicated in Fig. *20,* the time constant of this a.v.c. filter is 2 times .25, or .5 second. As far as the human eye is concerned, this is so short a time that the meter pointer appears to drop instantaneously to the lower value when a.v.c. action is introduced by ungrounding terminal *21*.

When a.v.c. filter resistor R_1 is made 10 megohms, the time constant becomes 10 times .25, or 2.5 seconds. Now the pointer drops more gradually to the lower value when the a.v.c. voltage is introduced; you can estimate the number of seconds and check with the computed value, if you desire.

In a practical radio receiver circuit, the time delay is ordinarily somewhere between .05 and .1 second. We used a higher time constant here only for demonstration purposes.

Instructions for Report Statement No. 57. Transfer to Report Statement No. 57 on the last page of this manual the two values which you recorded in Table *57* for an r.f. input voltage of 3 volts. One value was the d.c. output voltage across diode detector load resistor R_6 with a.v.c., and the other was the same measurement without a.v.c. These two values will tell us whether or not you assembled your apparatus correctly, aligned it properly, made the necessary adjustments and measured the required voltages satisfactorily.

Remember, of course, that you are not expected to duplicate the N.R.I. values which are given in the tables in these manuals. As was pointed out many times before in this Practical Demonstration Course, normal manufacturing tolerances in radio parts and normal variations which occur in circuits and test instruments make it highly improbable that you will secure exactly the same results that we did. We always take these normal tolerances into account when grading the values which you give in report statements.

EXPERIMENT 58

Purpose: **To build a frequency-modulated signal generator; to show that the audio modulation of a frequency-modulated signal generator cannot be detected by an ordinary amplitude type detector circuit, but can be detected when a frequency-discriminating circuit is used; to show that variations in the amount of frequency deviation affect the audio output but have no effect upon the r.f. carrier level.**

Preliminary Discussion. For this experiment, we will set up a frequency-modulated signal generator having the circuit shown in Fig. *24*. One triode section of the 6F8G tube generates the r.f. carrier frequency, and the other triode section generates an a.f. voltage for modulation purposes. This a.f. voltage across potentiometer R_8 is applied through R_{11} to the control grid of the 6SJ7GT pentode; this tube is connected to act like an inductance, and shunts the tank circuit of the r.f. oscillator. The a.f. voltage makes the inductance of the tube vary at an a.f. rate, thereby varying the *frequency* of the r.f. oscillator at the a.f. rate. As a result, we have *frequency modulation* of the r.f. oscillator. The circuit using the 6SJ7GT tube is called the *oscillator control circuit,* and the tube itself is called the *inductance tube.* The entire arrangement is similar to that employed in modern f.m. transmitters and in the automatic frequency control circuits of some radio receivers.

Both the r.f. and a.f. oscillator circuits are conventional in design, and similar to circuits used in previous experiments. D.C. plate current for the oscillator triode flows through feedback winding L_2, and is kept out of the grid circuit by d.c. blocking condensers C_2 and C_4.

The 6SJ7GT oscillator control tube gets its d.c. plate voltage from terminal *11* through r.f. tank inductance L_1 and 18,000-ohm resistor R_6. R_8 and R_9 form a voltage divider which provides the correct lower d.c. voltage for the screen grid.

Now let us see how the 6SJ7GT oscillator tube can act *as an inductance in parallel with* L_1. Referring to the schematic in Fig. *24*, note that two signal paths are shunted across L_1: *1.* R_6 in series with the plate-cathode path of the 6SJ7GT tube (by-pass condensers C_7 and C_4 and the chassis complete this r.f. path from the cathode to *18*); *2.* R_7, C_5 and C_6 (C_4 and the chassis complete this r.f. path from C_6 to *18*).

At radio frequencies, path R_7-C_5-C_6 is essentially resistive (reactances of C_5 and C_6 are low with respect to 40,000-ohm R_7), and hence r.f. current flowing over this path can be considered *in phase with its r.f. source voltage across* L_1. This r.f. current develops across C_6 an r.f. voltage which *lags the r.f. voltage across* L_1. The r.f. voltage across C_6 acts upon the control grid of the 6SJ7GT tube, making the tube pass an r.f. plate current which is *in phase with the applied r.f. grid voltage.* The r.f. plate current drawn from L_1 by the 6SJ7GT oscillator control tube *therefore lags the r.f. voltage across* L_1. This is exactly the same phase relationship as for an inductance load; the oscillator control tube thus acts like an additional inductance shunted across L_1, increasing the frequency of the r.f. oscillator.

(When two inductances are in parallel, the combined inductance is lower than that of the smaller inductance. Lowering the circuit inductance raises the frequency of the circuit.)

The a.f. voltage applied to the 6SJ7GT control grid through R_{11} makes the a.c. plate current vary at an audio rate, and consequently the inductance of this tube also varies at an audio rate. This in turn makes the frequency of the r.f. oscillator swing above and below its resting value at an a.f. rate, giving *frequency* modulation of the r.f. carrier without appreciable variation in the r.f. amplitude. (The *resting frequency* of an f.m.s.g. is the frequency produced by the r.f. oscillator when no a.f. voltage is applied to the control tube; this frequency is also known as the *center frequency.*)

If we connect the N.R.I. Tester across the output of the f.m.s.g. to measure the r.f. output voltage, we should obtain a meter reading. If we make the same connection for an aural listening test, however, there should be practically no audio tone; the N.R.I. Tester responds only to changes in amplitude, and the amplitude of the frequency-modulated r.f. output is essentially constant. Only the r.f. frequency varies in accordance with the audio signal, and the N.R.I. Tester cannot convert frequency changes into audible tones.

If we feed the frequency-modulated r.f. signal into a tuned r.f. transformer, however, and adjust the tuned secondary circuit to either side of resonance, a variation in the incoming r.f. signal *frequency* will cause a variation in r.f. *amplitude* due to the slope of the resonance curve, and this variation in amplitude will be equivalent to converting a frequency-modulated signal into an amplitude-modulated signal. When the N.R.I. Tester is connected across the tuned secondary of this r.f. transformer, an audible output tone should be obtained. For this reason, the r.f. transformer circuit (shown at the bottom of Fig. *24*) is called a *frequency-discriminating circuit*.

After demonstrating the action of a frequency-discriminating circuit, you will prove that the amount of frequency modulation (corresponding to the strength of the a.f. modulation) has no effect upon the r.f. level. This can be proved simply by setting the frequency-discriminating circuit to one side of resonance, then varying the a.f. voltage being fed to the oscillator control tube while listening to the headphone unit and watching the meter. The variations in the a.f. voltage should not change the r.f. output as indicated by the meter, but you should observe a definite change in volume in the headphone.

Step 1. To assemble on your s.g. chassis a frequency-modulated signal generator (f.m.s.g.) using the circuit of Fig. *24*, first take apart the amplitude-modulated signal generator on the s.g. chassis and the r.f. amplifier and detector stages on the experimental chassis, in the following manner:

a. Disconnect all power supply leads from the power pack output terminals.

b. Remove the 6F8G tube, then all fixed condensers, all fixed resistors and all leads above and underneath the *s.g. chassis* except the four power supply leads. Remove the 1000-ohm potentiometer. The only parts which you should now have left on your s.g. chassis are the audio transformer and *S.G.* coil above the chassis, and trimmer condenser C_A, the six-lug terminal strip, a tube socket in hole *s*, and the four power supply leads going to terminals *2*, *7*, *9* and *10*. If you desire, you can now flip over the twisted wires going from the grommet to *2* and *7* of *S*, so they have the position shown in Fig. *25*.

c. Remove every single part from the *experimental chassis*, including the power supply wires and all parts which are bolted to this chassis. Set aside the twisted wires for future use. Set aside the experimental chassis for use in Step 2; do not remove any of the notations on this chassis, for they will still be correct for future projects.

d. Mount a tube socket in hole *y* on the s.g. chassis, with its aligning slot next to the six-lug terminal strip. Identify this socket with a large letter *Y*, and identify the other socket (in hole *s*) with a large letter *S* on both sides of the chassis (see Fig. *25*).

e. Mount a 250,000-ohm potentiometer in hole *t*, with its lugs facing center of chassis.

f. Place a 13/16-inch long soldering lug (Part *6-16*) under the mounting nut of trimmer condenser C_A, and identify this lug as terminal *22*.

g. Wire your f.m.s.g. according to the step-by-step instructions given *underneath the schematic circuit diagram* in Fig. *24*, checking off each step with a pencil as you complete it. Try

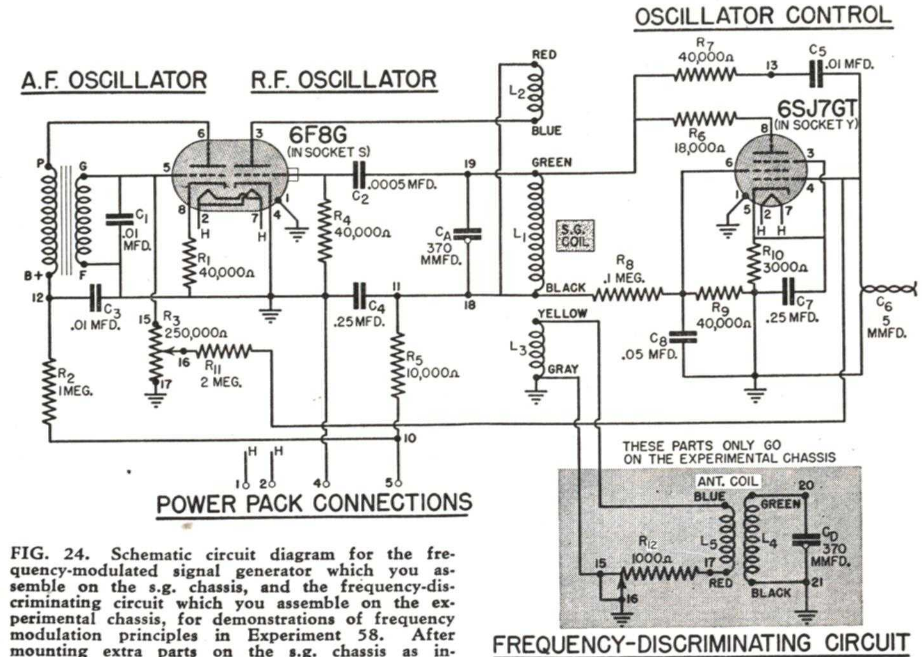


FIG. 24. Schematic circuit diagram for the frequency-modulated signal generator which you assemble on the s.g. chassis, and the frequency-discriminating circuit which you assemble on the experimental chassis, for demonstrations of frequency modulation principles in Experiment 58. After mounting extra parts on the s.g. chassis as instructed in Steps 1a through 1f, wire up the circuit by following the step-by-step instructions below.

A.F. Oscillator. Connect *2* and *7* of *S* to *2* and *7* of *Y* with twisted leads.
Connect *6* of *S* to *P* of a.f. transformer, through *a*.
Connect *12* to *B+* of a.f. tr. through *b*.
Connect 1-meg. resistor R_2 between *12* and *10*.
Ground *F* of a.f. tr. to *9* through *c*.
Connect .01-mfd. condenser C_3 between *B+* and *F* of a.f. tr.
Connect *5* of *S* to *G* of a.f. tr. through *d*.
Connect .01-mfd. condenser C_1 between *4* and *5* of *S*.
Connect 40,000-ohm resistor R_1 between *1* and *8* of *S*.
Ground *1* of *S* to *9*.
Connect *5* of *S* to *15*.
Ground *17* to *9*.

R.F. Oscillator. Connect *1* and *4* of *S*.
Connect *3* of *S* to *blue* of *S.G.* coil through *f*.
Connect .25-mfd. condenser C_4 between *17* and *11*.
Connect grid clip lead to *unmarked* terminal of *S.G.* coil.
Connect .0005-mfd. condenser C_2 between *green* and *unmarked* *S.G.* coil terminals.
Connect *black* of *S.G.* coil to *18* through hole *gg*.
Connect *black* of *S.G.* coil to *11* through hole *g*.
Connect *red* of *S.G.* coil to *11* through *e*.
Connect *green* of *S.G.* coil to *19* through *h*.
Ground *gray* of *S.G.* coil to *14* through *j*.
Connect 10,000-ohm resistor R_5 between *10* and *11*.

Oscillator Control Circuit. Connect 100,000-ohm resistor R_8 between *6* of *Y* and *11*.
Connect .05-mfd. condenser C_8 between *1* and *6* of *Y*.
Connect 40,000-ohm resistor R_9 between *6* of *Y* and *9*.
Connect .25-mfd. condenser C_7 between *5* of *Y* and *22*.
Connect three 1,000-ohm resistors in series (R_{10}) between *5* of *Y* and *22*, as shown in Fig. *25*.
Connect *3* and *5* of *Y*.
Connect 2-meg. resistor R_{11} between *4* of *Y* and *16*.
Connect 18,000-ohm resistor R_6 between *8* of *Y* and *19*.
Connect 40,000-ohm resistor R_7 between *19* and *13*.
Connect .01-mfd. condenser C_5 between *4* of *Y* and *13*.
Ground *1* of *Y* to *14*.
Connect a 4½" wire to *1* of *Y*, connect a 4½" wire to *4* of *Y*, and twist the wires together to form 5-mmfd. capacity C_6.
Connect a 40,000-ohm resistor (R_4, in the r.f. oscillator) between *gray* and *unmarked* *S.G.* coil terminals. IMPORTANT: Do *not* connect R_4 to the *green* *S.G.* coil terminal this time.
Connect a 4" wire to *gray* of *S.G.* coil.
Connect a 4" wire to *yellow* of *S.G.* coil.

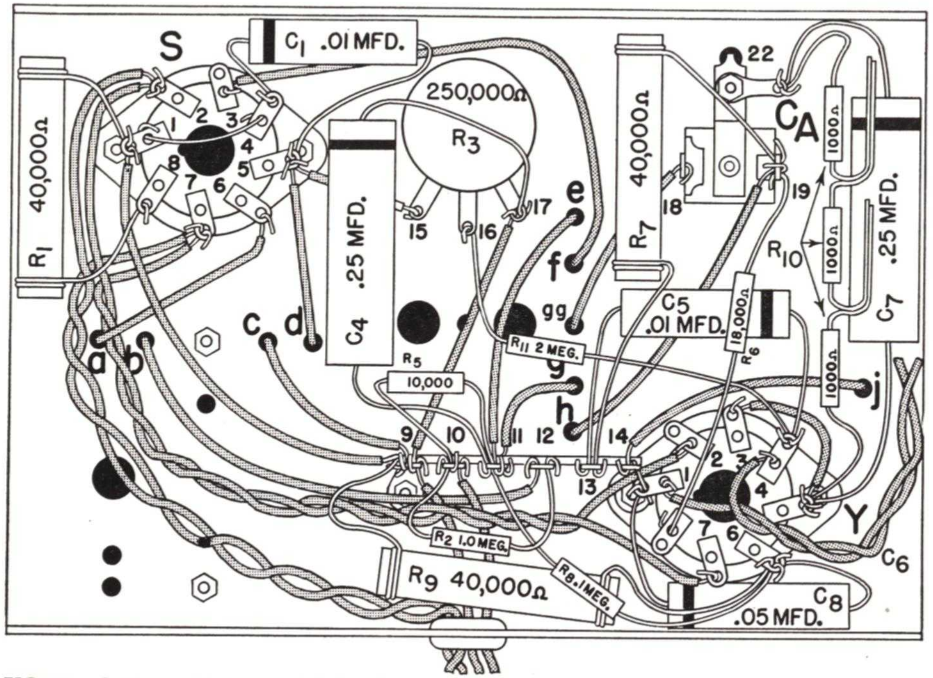


FIG. 25. Semi-pictorial bottom view of the s.g. chassis after completion of all wiring for the frequency-modulated signal generator used in Experiment 58. The two wires which are connected to terminals *1* and *4* of socket *Y* and twisted together merely provide a 5-mmfd. capacity between these two circuit terminals; be sure the bare ends of the wires do not touch any metal parts.

to complete all wiring by referring only to this schematic, using the bottom and top views in Figs. *25* and *26* as guides only when absolutely necessary.

h. When all wiring is completed, check your work carefully against the bottom and top views in Figs. *25* and *26*. Working from one type of diagram and checking carefully against another type makes it almost impossible for errors to get by.

i. Insert the 6F8G tube in socket *S*, insert the 6SJ7GT tube in socket *Y*, then set aside this f.m.s.g. temporarily.

Step 2. To assemble a frequency-discriminating circuit on your experimental chassis and connect it to your f.m.s.g., proceed as follows while using the schematic circuit diagram in Fig. *24* and the top view in Fig. *26* as guides:

a. Mount a 370-mmfd. trimmer condenser in hole *nn*. The markings on the chassis should identify it as C_D, with terminals *20* and *21*.

b. Mount the antenna coil in holes *jj* and *pp*, with the lugs above holes *a*, *b*, *c* and *d*.

c. Mount the 1000-ohm wire-wound potentiometer R_{12} in hole *t*, with the lugs toward the center of the chassis so that they will be identified as *15*, *16* and *17* respectively.

d. Connect *21* to *black* of *ANT.* coil through *b*.

e. Connect *20* to *green* of *ANT.* coil through *a*.

f. Ground *21* to *16*.

g. Connect *17* to *red* of *ANT.* coil through *c*.

h. Connect *15* to *16*.

i. Connect a 6″ wire to *blue* of *ANT.* coil, bringing wire down through *d*, then out the side of the chassis.

j. Connect a 6″ wire to *15*, and bring this wire out the same side of the chassis as the preceding wire.

k. Rotate the potentiometer *(R_{12}* in Fig. *24)* as far clockwise as it will go. It is used simply as a 1000-ohm fixed resistor in this circuit, so will not be adjusted any more.

l. Connect your frequency-discriminating circuit to the f.m.s.g. (connect lead from *blue* of *ANT.* coil to lead from *yellow* of *S.G.* coil, then connect the remaining two leads together). Your apparatus should now appear as shown in Fig. *26*.

m. Connect the four power supply leads of your completed f.m.s.g. to the power pack output terminals in the usual manner.

Step 3. To check the performance of your f.m.s.g. and frequency-discriminating circuit, prepare the N.R.I. Tester for listening to audio signals and connect it to the output of your f.m.s.g. (red clip on *yellow* of *S.G.* coil, black clip on chassis, selector switch at *V),* set s.g. trimmer C_A about one turn off from maximum capacity, then turn on all apparatus. You are now feeding a frequency-modulated r.f. signal into the N.R.I. Tester.

Rotate f.m.s.g. potentiometer R_3 back and forth several times while listening to the headphone and watching the meter, to note the effect of this adjustment upon the r.f. signal level indicated by the meter and the audio tone reproduced by the headphone. (Some distortion in the form of amplitude modulation is present in this simple f.m.s.g. circuit, and the N.R.I. Tester reproduces this as an audio tone).

Adjust R_3 to the point at which you can just barely hear the audio tone (if you can hear the tone at all positions of R_3, set R_3 one-quarter turn off from its maximum *counter-clockwise* position). Now connect the N.R.I. Tester to the output of your frequency-discriminating circuit (red clip on *green* of *ANT.* coil, black clip on either chassis). Adjust trimmer C_D for a maximum meter deflection. This adjusts your frequency-discriminating circuit to the peak (*a*) of the resonant response curve in Fig. *27*.

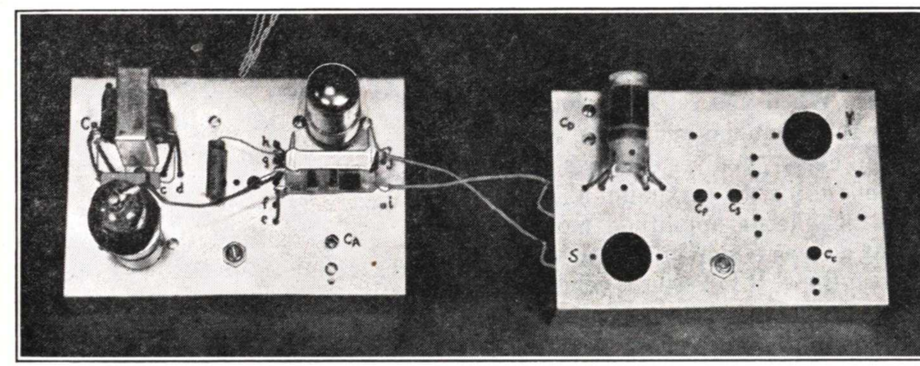


FIG. 26. Top view showing the completely assembled f.m.s.g. on the s.g. chassis (left) and the frequency-discriminating circuit on the experimental chassis (right), just before power pack connections are made.

Having found the peak position for C_D, rotate this condenser on either side of the peak setting while listening to the headphone unit and watching the meter. Note that the audio volume increases as you tune off resonance in either direction, and note how the meter reading (the r.f. voltage) varies as you tune off resonance.

Finally, set trimmer C_D to a point which gives you about ⅔ of the maximum obtainable meter reading, then rotate f.m.s.g. potentiometer R_3 in either direction while watching the meter and listening to the headphone unit. R_3 varies the strength of the a.f. signal, and consequently the audio tone in the phone should vary with the setting of R_3, and the meter reading should remain essentially constant.

Discussion: When the N.R.I. Tester is connected across the output terminals of the frequency-modulated signal generator, the audio tone which you hear is due to amplitude modulation occurring along with frequency modulation. You will find, however, that this audio tone is quite weak in the phone unit even with the N.R.I. Tester set for maximum sensitivity (*V* range). When you set potentiometer R_3 for the minimum audio tone which you can detect, you are simply setting the f.m.s.g. for the maximum a.f. output which keeps amplitude modulation at an acceptable minimum value.

When the N.R.I. Tester is connected across the tuned circuit of the frequency-discriminating circuit and this is tuned off the peak or resonant position, the audio tone becomes louder, indicating that this circuit is successfully converting the frequency-modulated signal into an amplitude-modulated signal.

The curve in Fig. *27* represents the resonant response curve of the tuned circuit which you are using as a frequency-discriminating circuit. When this is tuned so that its resonant frequency is exactly the same as the resting frequency of the r.f. oscillator in the f.m.s.g., our operating point is at *a* in Fig. *27*, and the a.f. modulation swings the r.f. oscillator frequency above and below *a*, to points *1* and *2*. Since the peak of this resonant response curve is almost flat, this swing in frequency gives only a small variation in amplitude, and the resulting audio signal is very weak.

Remembering that the resting frequency of the f.m.s.g. is fixed (being determined by the setting of C_A and other circuit capacities), let us detune the frequency-discriminating circuit. This has the effect of shifting the operating point to *b*, on the slope of the curve in Fig. *27*. **(Actually, detuning shifts the entire resonance curve to the right while leaving the resting frequency fixed.)** The a.f. modulation now swings the r.f. oscillator frequency between points *3* and *4* on the curve, causing the amplitude of the output voltage across C_D to

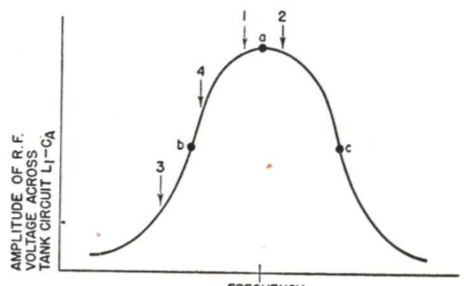


FIG. 27. Frequency response curves for resonant circuit L_4-C_D of the frequency-discriminating circuit which you use in Experiment 58.

vary in proportion to the vertical distance between these points. The swings in frequency are thus converted into variations in r.f. amplitude corresponding to a strong audio signal. We still have only r.f. voltages across C_D, however; they must be demodulated in a conventional manner by the N.R.I. Tester before we can hear the audio modulation.

Thus, we find that as the frequency-discriminating circuit is tuned off resonance, a given frequency change produces a much greater change in amplitude, and consequently the audio tone becomes louder even though the average r.f. voltage, as indicated by the N.R.I. Tester, decreases. (In other words, when C_D is set to give

point *b* in Fig. *27* as the operating point, the meter indicates the r.f. voltage at point *b;* it cannot follow the swings above and below b, to *3* and *4,* because these swings occur at an a.f. rate.)

Instructions for Report Statement No. 58. With the headphone plugged into the N.R.I. Tester and with the selector switch at *3* × *V*, adjust trimmer C_D slowly over its entire range from 0 to 3 turns off maximum capacity.

There will be two settings (corresponding to points *b* and *c* in Fig. *27)* at which you obtain maximum headphone volume; record in the margin of this page the meter reading on the *AC* scale for each maximum-volume setting. Now adjust C_D for maximum meter deflection (corresponding to point *a* in Fig. *27*), and record this *AC* scale reading also in the page margin. Transfer your three meter readings to Report Statement No. 58. (The headphone prevents you from making true voltage measurements, so record the actual meter reading on the *AC* scale.)

EXPERIMENT 59

***Purpose:* To build a superheterodyne receiver; to show that d.c. continuity exists between each positive vacuum tube electrode and the cathode of the rectifier tube; to show that each cathode and negative electrode must have d.c. continuity to a plate of the rectifier tube; to show that plate and screen grid electrodes are positive with respect to the chassis; to show that control grid electrodes are negative with respect to their cathodes.**

Step 1. To build the equivalent of a complete 5-tube superheterodyne receiver according to the circuit of Fig. 28, proceed as follows:

a. Disconnect from the power pack output terminals the power supply wires, and remove the tubes from the s.g. chassis. Now take your metal-marking crayon and identify the experimental chassis (on which the frequency-discriminating circuit is mounted) as *CHASSIS A,* with prominent large letters somewhere on top of the chassis or on the side. In the same manner, identify the s.g. chassis as *CHASSIS B.* From now on, this marking will serve to distinguish between the two chassis units.

b. Unsolder all leads from *CHASSIS A* and *CHASSIS B,* then remove all mounted parts. Leave the lettering on each chassis exactly as it was, strengthening any letters which are not clear.

c. Wire up your superheterodyne receiver by using the schematic circuit diagram in Fig. *28* as your guide and following the step-by-step instructions given on the page opposite this diagram. Refer to Fig. *4* for locations of mounting holes. Start with *CHASSIS A,* on which you place the frequency converter and part of the i.f. amplifier. After this, hook up the rest of the i.f. amplifier, the second detector and the a.f. amplifier on *CHASSIS B.* Finally, connect together chassis units *A* and *B.* Always connect the *OUTSIDE FOIL* lead of a condenser to the terminal which is closer to ground potential.

d. When all wiring is completed according to the instructions given on the page opposite Fig. *28,* check your work carefully against the semi-pictorial diagrams in Figs. *29* and *30.* The actual under-chassis connections should now appear essentially as shown in Fig. *31.* Now connect to the power pack output terminals the four power supply leads coming from *CHASSIS B.*

e. Insert 6F8G tube in socket *S* of *CHASSIS B,* and place the grid clip on its top cap.

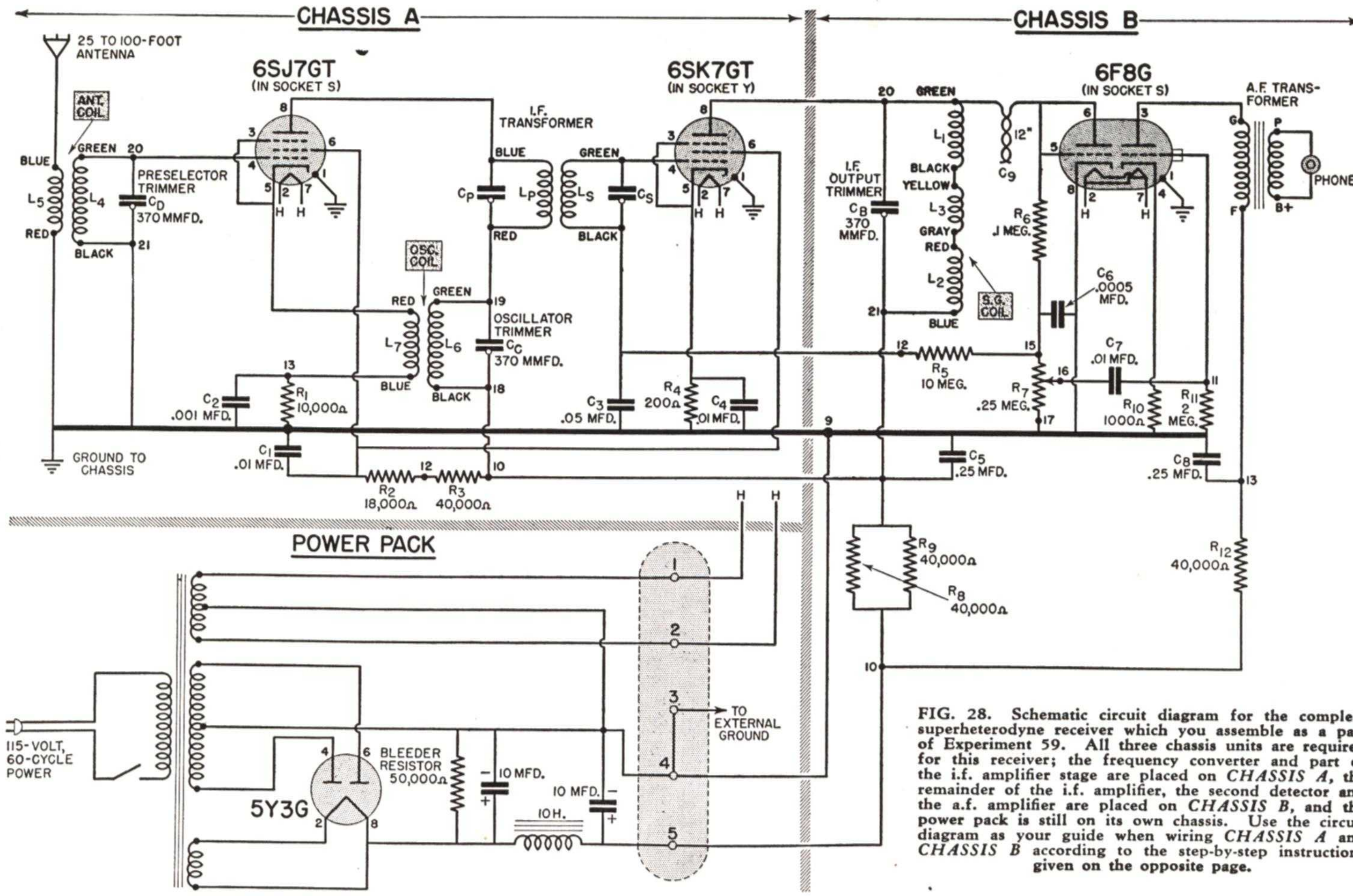


FIG. 28. Schematic circuit diagram for the complete superheterodyne receiver which you assemble as a part of Experiment 59. All three chassis units are required for this receiver; the frequency converter and part of the i.f. amplifier stage are placed on *CHASSIS A*, the remainder of the i.f. amplifier, the second detector and the a.f. amplifier are placed on *CHASSIS B*, and the power pack is still on its own chassis. Use the circuit diagram as your guide when wiring *CHASSIS A* and *CHASSIS B* according to the step-by-step instructions given on the opposite page.

Chassis A. **Mount an octal socket in *s*, with aligning slot toward *aa*. Place a 13/16" soldering lug underneath chassis on screw going through *aa*, and identify as *23*.**
Mount an octal socket in hole *y*, with aligning slot toward hole *ll*. Place a 13/16-inch soldering lug on screw for *mm*, and identify it as terminal *24*.
Mount a 6-lug terminal strip in holes *kk* and *ll*, with lugs nearest center of chassis.
Mount a 370-mmfd. trimmer condenser in hole *nn*.
Mount a 370-mmfd. trimmer condenser in hole *dd*.
Mount the i.f. transformer in hole *ff*, with *red* and *green* terminals toward the 6-lug terminal strip.
Mount *ANT*. coil on top of chassis in *jj* and *pp*, with lugs near *a*, *b*, *c* and *d*.
Mount *OSC*. coil on top of chassis in *hh* and *ii*, with lugs near *e*, *f*, *g* and *h*.
Connect *2* and *7* of *S* to *2* and *7* of *Y* with twisted wires (use the 9" twisted wires which you removed from the experimental chassis).
Connect 8" twisted wires to *2* and *7* of *Y*.
Connect an 8" wire to *blue* of *ANT*. coil, bring down through *d*, then out open end of chassis. Tie knot in free end to identify it as *antenna* wire.
Connect *23* to *red* of *ANT*. coil through *c*.
Connect *21* to *black* of *ANT*. coil through *b*.
Connect *21* to *9*.
Connect *20* to *green* of *ANT*. coil through *a*.
Connect *20* to *4* of *S*.
Connect *3* and *5* of *S*.
Connect *3* of *S* to *red* of *OSC*. coil through *f*.
Connect *13* to *blue* of *OSC*. coil through *e*.
Connect 10,000-ohm resistor R_1 between *13* and *14*.
Connect .001-mfd. condenser C_2 between *13* and *14*.

Connect *8* of *S* to *blue* of i.f. transformer.
Connect *19* to *red* of i.f. transformer.
Connect *19* to *green* of *OSC*. coil through *h*.
Connect *18* to *black* of *OSC*. coil through *g*.
Connect *18* to *10*.
Connect *1* of *S* to *23*.
Connect .01-mfd. condenser C_1 between *1* and *6* of *S*.
Connect *4* of *Y* to *green* of i.f. transformer.
Connect *3* and *5* of *Y*.
Connect 200-ohm resistor R_4 between *14* and *5* of *Y*.
Connect .01-mfd. condenser C_4 between *14* and *3* of *Y*.
Ground *1* of *Y* to *14*.
Connect .05-mfd. condenser C_3 between *1* of *S* and *black* of i.f.
Connect *6* of *S* to *6* of *Y*.
Connect 40,000-ohm resistor R_3 between *10* and *12*.
Connect 18,000-ohm resistor R_2 between *12* and *6* of *Y*.

Chassis B. Mount an octal socket in *s*, with aligning slot toward *aa*. Place a 13/16" soldering lug on screw for *aa*, and identify it as terminal 25.
Mount the 6-lug terminal strip in holes *kk* and *ll*, with lugs nearest center of chassis.
Mount 250,000-ohm potentiometer R_7 in hole *t*, with lugs toward center of chassis.
Mount a 370-mmfd. trimmer condenser in hole *nn*.
Mount *S.G.* coil on top of chassis in *jj* and *pp*, with lugs near *a*, *b*, *c* and *d*.
Mount a.f. transformer on top of chassis in *gg* and *ii*, with lugs near *e*, *f*, *g* and *h*.
Connect twisted wires about 12" long to *2* and *7* of *S*, and bring out through *k*.
Connect an 8" wire to *9*, through grommet *k*.
Connect a 10" wire to *10*, bring through grommet, and tie knot in end.

Connect *20* to *green* of *S.G.* coil through *a*.
Connect *black* and *yellow* of *S.G.* coil.
Connect *gray* and *red* of *S.G.* coil.
Connect *21* to *blue* of *S.G.* coil through *c*.
Connect *5* and *6* of *S*.
Connect 12" wire to *6* of *S*, connect 12" wire to *20*, twist wires together, and arrange as in Fig. *30* to form capacity C_9.
Connect 100,000-ohm resistor R_6 between *5* of *S* and *15*.
Connect *1* and *8* of *S* to *25*.
Connect *17* to *14*.
Connect .0005-mfd. condenser C_6 between *15* and *17*.
Connect .01-mfd. condenser C_7 between *16* and *11*.
Connect *11* to *unmarked* of *S.G.* through *ee*.
Connect lead with grid clip to *unmarked* of *S.G.*
Connect 2-megohm resistor R_{11} between *11* and *17*.
Connect 1,000-ohm resistor R_{10} between *1* and *4* of *S*.
Connect *3* of *S* to *G* of a.f. trans. through *e*.
Connect *13* to *F* of a.f. trans. through *f*.
Connect a 10" wire to *B+* of a.f. trans., bring down through *G*, then up through *i* to serve as a.f. output lead.
Connect a 10" wire to *P* of trans., bring down through *h*, then up through *j* to serve as a.f. output lead.
Connect two 40,000-ohm resistors (R_8 and R_9) in parallel between *21* and *10*.
Connect .25-mfd. condenser C_5 between *21* and *9*.
Connect 40,000-ohm resistor R_{12} between *10* and *13*.
Connect .25-mfd. condenser C_8 between *13* and *14*.
Connect 10-megohm resistor R_5 between *15* and *12*.

(Continued on next page)

(Continued from preceding page)

Inter-Chassis Wiring. The notations *A, B, C, D, E,* and *F* in Figs. *29* and *30* represent the following connections:

With apparatus arranged as in Fig. *31*, connect *24* in *A* to *25* in *B* with a 5" wire.

Connect *2* and *7* of *Y* in *A* to *2* and *7* of *S* in *B* with the 8" twisted wires already on *2* and *7* of *Y*.

Connect *black* of i.f. trans. in *A* to *12* in *B* with 15" wire.

Connect *8* of *Y* in *A* to *20* in *B* with 5" wire.

Connect *10* in *A* to *21* in *B* with 8" wire.

---

f. Insert the 6SK7GT tube in socket *Y* of *CHASSIS A.*

g. Insert the 6SJ7GT tube in socket *S* of *CHASSIS A.*

h. Connect your headphone unit to the two a.f. output leads at the right of *CHASSIS B,* by pushing back the insulation from each lead, then winding the bare wire a few times around each headphone tip. Your completed superheterodyne receiver should now appear as shown in Fig. *32.*

Step 2. To secure experience in making continuity tests in a superheterodyne circuit, use the ohmmeter ranges of the N.R.I. Tester to measure the resistance between each positive electrode and the cathode of the rectifier tube in your power pack. Make these measurements in the order in which they are given in the left-hand section of Table *59,* and record each result in this table. Be sure the power pack is disconnected from the power source during ohmmeter tests.

Next, complete your continuity tests by measuring the resistance between one of the rectifier tube plates and each cathode and control grid, in the order set forth in Table *59,* and record each result in this table.

Since the diode detector does not receive any d.c. voltages from the power pack, there is no need to make continuity tests on the diode electrodes when checking d.c. supply circuits.

In the case of a type 6X5GT rectifier tube, the cathode is *8* and the two plates are *3* and *5.* In the case of a type 5Y3G rectifier tube, a filament terminal should be used as the cathode, since the filament also serves as the cathode; the two plate terminals are *4* and *6.*

Step 3. To secure experience in measuring d.c. electrode voltages in a superheterodyne circuit, make each of the voltage measurements called for in the right-hand section of Table *59,* and record your results in this table. Be sure to turn off the power pack while moving the test clips in between measurements, to avoid being shocked and to avoid accidental shorting of circuit terminals with the test clips.

Discussion: In the superheterodyne receiver which you have just constructed according to the circuit of Fig. *28,* the 6SJ7GT tube serves as oscillator-mixer-first detector. The 6SK7GT is the i.f. amplifier tube, while the 6F8G is the second detector and a.f. output tube. Since the 6F8G has two triode sections, and since the rectifier tube in the power pack is also serving the receiver, we have the equivalent of a 5-tube receiver.

If you use the schematic circuit diagram as your guide while making continuity tests in your superheterodyne receiver, you should be able to predict beforehand what the measured resistance will be for each measurement. For example, the d.c. path between the plate of the 6SJ7GT tube and the cathode of the rectifier tube includes L_P, L_6, two 40,000-ohm resistors (R_8 and R_9) in parallel, and the 10-henry choke coil in the power pack. You know that the choke coil

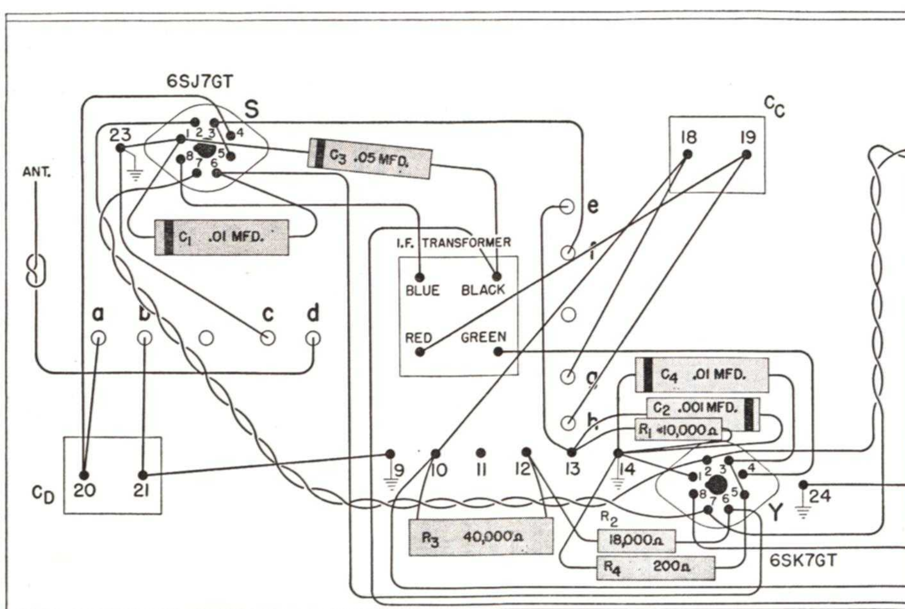


FIG. 29. Simplified semi-pictorial bottom view of *CHASSIS A,* showing all wiring. In this type of diagram, the parts are usually shown slightly smaller than in true proportion, for clearness. All connections are made at terminals, so cross-overs of lines do not mean connections. Connections at the right, labeled *A, B, C, D, E,* and *F* go to correspondingly marked leads in *CHASSIS B* (Fig. 30), but these connections are not made until after you wire *CHASSIS B*

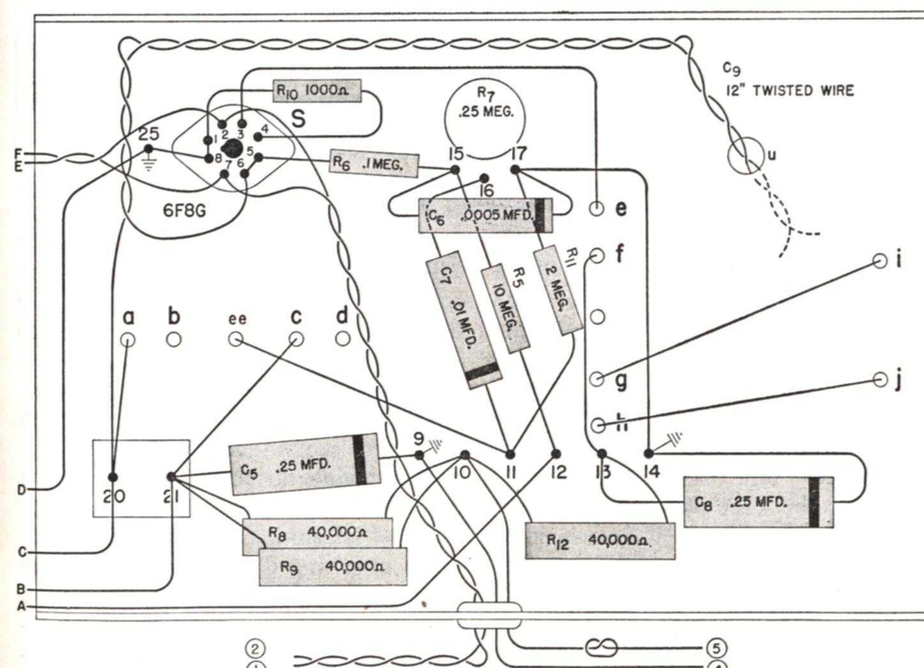


FIG. 30. Simplified semi-pictorial wiring diagram for *CHASSIS B* of your superheterodyne receiver. The leads at the left go to corresponding leads in *CHASSIS A* (Fig. *29*). The leads at the bottom of this diagram are connected to the power pack in the usual manner. The two a.f. output leads go up through chassis holes *i* and *j.*

resistance is around 200 ohms, which is negligible in comparison to the 20,000-ohm combined resistance of the resistors. Likewise, the d.c. resistance of the r.f. coils is negligible, so the essential resistance in this path is 20,000 ohms. Each 40,000-ohm resistor can have up to 20% tolerance in value, however; this means that any measured resistance value between about 16,000 ohms and about 24,000 ohms for this circuit can be considered satisfactory. The N.R.I. value for this measurement happened to agree exactly with the computed value.

Here is another example: The d.c. path between the cathode of the a.f. amplifier triode section of the 6F8G tube and a plate of the rectifier tube includes 1000-ohm cathode resistor R_{10} and half of the high-voltage secondary winding of the power transformer. The resistance of half of the high-voltage winding on a power transformer like this is ordinarily somewhere between 500 and 750 ohms, so we consider the N.R.I. measured value of 1700 ohms as entirely satisfactory for this path. You can readily measure the resistance of the winding yourself if you desire.

The resistance values which you measure should verify the basic servicing rules set forth in the purpose of this experiment. A Radiotrician utilizes these continuity tests extensively in his work, but at the same time realizes that a receiver can operate unsatisfactorily or be dead even when continuity tests give perfect results. There are many points in receiver circuits at which defects can block a signal circuit without destroying d.c. continuity or d.c. voltage distribution. Thus, a short circuit in an r.f. coil, a shorted or open by-pass condenser or a break in a signal circuit lead can affect receiver operation without being revealed by the routine continuity tests in this experiment. A d.c. continuity test simply tells whether d.c. supply circuits are complete. You must also be on the look-out for shorted parts across the d.c. supply circuits; these shorts can also be checked with an ohmmeter. In the next experiment, however, you will practice other servicing techniques which do reveal signal circuit defects.

The first thing a Radiotrician does when checking d.c. continuity in any vacuum tube circuit is to locate the highest *positive* terminal in the system; this is the cathode of the rectifier tube, so he locates the rectifier tube first, then refers to a tube chart or chassis layout to determine which

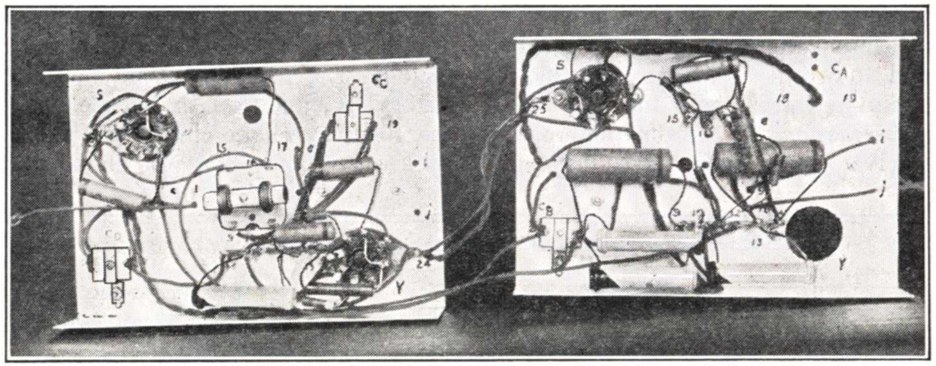


FIG. 31. Bottom views for *CHASSIS A* and *CHASSIS B*, showing how these units should appear after all wiring has been completed and all inter-connections made.

NATURE OF CONTINUITY MEASUREMENT	RESISTANCE IN OHMS	
	YOUR VALUE	N.R.I. VALUE
PLATE (8) OF 6SJ7GT TO RECTIFIER CATHODE		20,000
SCREEN GRID (6) OF 6SJ7GT TO RECTIFIER CATHODE		70,000
PLATE (8) OF 6SK7GT TO RECTIFIER CATHODE		20,000
SCREEN GRID (6) OF 6SK7GT TO RECTIFIER CATHODE		70,000
PLATE (3) OF 6F8G TO RECTIFIER CATHODE		40,000
CONTROL GRID (4) OF 6SJ7GT TO RECTIFIER PLATE		600
CATHODE (5) OF 6SJ7GT TO RECTIFIER PLATE		10,000
CONTROL GRID (4) OF 6SK7GT TO RECTIFIER PLATE		10 MEG.
CATHODE (5) OF 6SK7GT TO RECTIFIER PLATE		800
CONTROL GRID (T.C.) OF 6F8G TO RECTIFIER PLATE		2 MEG.
CATHODE (4) OF 6F8G TO RECTIFIER PLATE		1,700

NATURE OF ELECTRODE VOLTAGE MEASUREMENT	D.C. VOLTAGE IN VOLTS	
	YOUR VALUE	N.R.I. VALUE
PLATE (8) OF 6SJ7GT TO CHASSIS		220
SCREEN GRID (6) OF 6SJ7GT TO CHASSIS		65
C BIAS ACROSS 10,000Ω CATHODE RESISTOR		30
PLATE (8) OF 6SK7GT TO CHASSIS		200
SCREEN GRID (6) OF 6SK7GT TO CHASSIS		65
CONTROL GRID (4) OF 6SK7GT TO CATHODE (5) OF 6SK7GT		1.0
PLATE (3) OF 6F8G TO CHASSIS		180
CONTROL GRID (T.C.) OF 6F8G TO CATHODE (4) OF 6F8G		5.1

TABLE 59. Record your results here for Experiment 59, in which you make continuity tests and d.c. electrode voltage measurements in your five-tube superheterodyne receiver.

prong is the cathode of that tube.

Having checked continuity between each positive vacuum tube electrode and the cathode of the rectifier tube, the Radiotrician next locates the most *negative* terminal in the circuit. In an a.c.-operated receiver, this is the center tap on the high-voltage secondary winding of the power transformer; since the ends of this winding go to the two plates of the rectifier tube, he usually chooses one plate of the rectifier tube for this most negative terminal, and includes the resistance of half the winding in each of his measurements.

Some servicemen, when making continuity tests with an ohmmeter, merely make sure that there is no short circuit or open circuit between the points under test; other servicemen will estimate what the resistance should be by referring to the schematic circuit diagram, and make sure that the measured resistance agrees to within about 25% with this computed value. We make the actual measurements in this experiment to secure the valuable experience which it gives, even though these measurements would ordinarily be unnecessary when followed by signal circuit tests.

Still other servicemen contend that if all vacuum tubes are receiving correct d.c. electrode voltages, d.c. continuity must also exist and continuity tests are therefore unnecessary. As a Radiotrician, you will generally prefer one method to the other, or will use whichever method (continuity or electrode voltage tests) appears more suitable for the particular situation at hand.

Your voltage measurements should indicate that even though the plates of the 6SJ7GT and 6SK7GT tubes are connected to the same voltage supply terminal, the 6SJ7GT mixer-first detector tube has a slightly higher plate voltage. This is due to the fact that the oscillator stage is producing an r.f. voltage even when no signals are being picked up. The r.f. voltage produced across L_6 and L_P adds to the d.c. voltage and makes the voltage measurement higher than it actually is. Shorting oscillator coil L_6 would give better agreement between measured plate voltage values.

The C bias value for the first detector is measured directly across the 10,000-ohm cathode resistor, to eliminate any oscillator r.f. voltages from this measurement. This C bias voltage is high, as required for proper detection.

The 6SK7GT i.f. amplifier tube has a low C bias, to provide high gain initially on weak signals, but this bias is greatly increased by the a.v.c. action on strong signals. The actual bias in this case is about twice the measured value, for 10-megohm a.v.c. resistor R_5 is in series with the grid circuit, and hence is in series with the 10-megohm input resistance of the N.R.I. Tester. The circuit resistance of 10 megohms acts like a voltage multiplier resistor used with the tester.

The 6F8G output tube likewise has a low C bias, as required for maximum power output without distortion. There is only 2 megohms (R_{11}) in series with the tester during this measurement, so this tester reading is fairly close to the correct value.

The screen grid voltages on the first detector and the i.f. tube are about one-third of the plate voltages in each case, an entirely normal condition.

Instructions for Report Statement No. 59. Although the most important continuity tests are those made between electrodes of tubes, it is sometimes necessary in radio servicing to check continuity between other points in the circuit. For example, in the superheterodyne circuit you are using, it may be necessary to check continuity in the diode circuit, between terminal *5* of the 6F8G tube and the chassis, in order to determine if the volume control is defective.

For this report statement, we will duplicate the volume control defect in which the resistance element is open internally near the grounded terminal (*17*). To do this, remove the three leads which are on terminal *17* in *CHASSIS B*, leaving these leads connected together and making sure that they do not touch any nearby parts. With power off, check continuity now between *5* of *S* in *CHASSIS B* and the chassis, then answer Report Statement No. 59.

EXPERIMENT 60

***Purpose:* To align your superheterodyne receiver for broadcast station reception.**

Step 1. To align your superheterodyne receiver so it has an i.f. value of about 480 kc., then tune the receiver to a broadcast station having a frequency somewhere between 550 kc. and 1200 kc., **proceed as follows:**

a. Connect the knotted antenna lead from *CHASSIS A* to an outdoor antenna, preferably one between 50 and 100 feet long. If you already have an all-wave or noise-reducing doublet antenna, simply connect the knotted antenna lead to one terminal of the doublet. If no outdoor antenna is available and you do not wish to erect a permanent one, take about 50 feet of wire (any type; bell wire is entirely suitable), connect one end to the receiver, pass the wire out through a window, then anchor the far end to some convenient high point such as a tree. If you are fairly close to a powerful station operating between 550 and 1200 kc., a 25-foot long in-

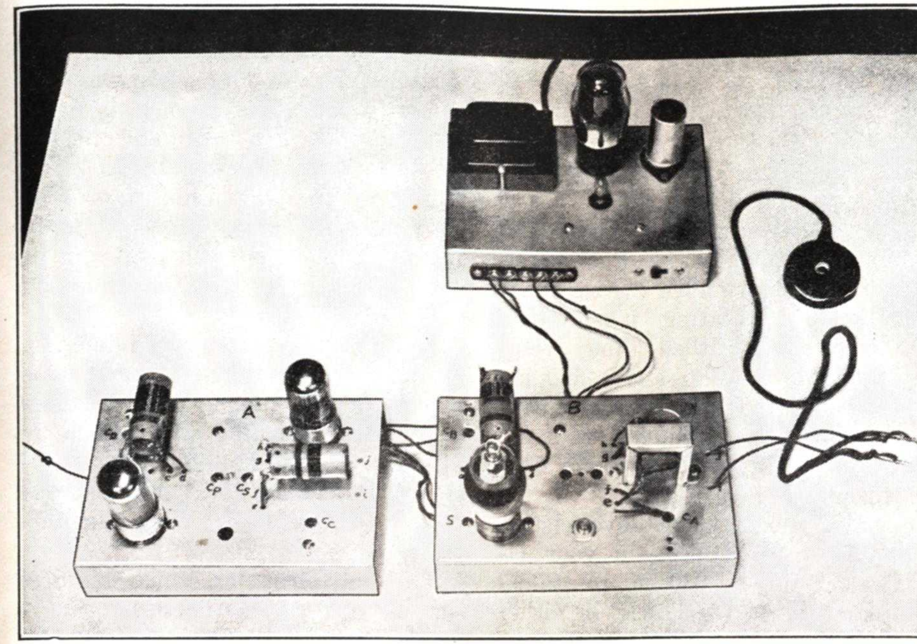


FIG. 32. View of the completed superheterodyne receiver, as connected to the power pack, headphone and antenna for reception of a radio program. In Experiments 59 and 60, you practice professional servicing techniques on this receiver.

sulated wire strung around the room may be sufficient.

If difficulty is encountered in tuning in a station with your antenna, connect the antenna to the *green* terminal of the *ANT.* coil; this alternative connection may be more satisfactory, particularly when using an antenna shorter than 50 feet.

b. Check the power supply leads from *CHASSIS B* to make sure they are connected properly to the power pack output terminals, and make sure that your external ground wire is connected to power pack output terminal *3*. This ground wire will also serve the signal circuits of the receiver, for examination of the schematic in Fig. *28* shows that all chassis grounds in the signal circuits go to output terminal *4* of the power pack, then to *3* and the ground wire by means of the shorting wire on the terminal strip.

c. Connect the N.R.I. Tester as a visual output indicator for your receiver by connecting it to measure the d.c. voltage between terminal *12* of *CHASSIS B* and the chassis (black clip on *12*). (We include the 10-megohm a.v.c. filter resistor R_5 in this a.v.c. voltage measurement simply to keep a.f. signals out of the N.R.I. Tester; these signals might cause flickering of the pointer, making adjustments difficult.) Switch to the *V* range, then turn on the power pack and the N.R.I. Tester.

d. Rotate the potentiometer on *CHASSIS B* clockwise as far as it will go, to secure maximum a.f. output voltage.

e. Tighten all five trimmer condensers (preselector trimmer C_D, oscillator trimmer C_C, i.f. primary trimmer C_P and i.f. secondary trimmer C_S on *CHASSIS A*, and i.f. trimmer C_B on *CHASSIS B*) so as to set each to maximum capacity.

f. Set i.f. primary trimmer C_P and i.f. secondary trimmer C_S each to about 480 kc. by rotating each 3/8 turn counter-clockwise, then rotate i.f. trimmer C_B 1/2 turn counter-clockwise. This aligns your entire i.f. amplifier approximately to 480 kc.

g. While listening to the phone and looking occasionally at the meter, tune oscillator trimmer C_C to about 1160 kc. by rotating it 5/8 turn counter-clockwise, then tune preselector trimmer C_D to about 680 kc. by rotating it 1/2 turn counter-clockwise. This tunes the entire preselector roughly for reception of a 680-kc. signal.

h. Since you may not have a sufficiently powerful station in your vicinity operating on 680 kc., rotate oscillator trimmer C_C slowly in either direction from its present setting until you hear a broadcast program in the headphone. Adjust oscillator trimmer C_C carefully for maximum volume once you find a station, then adjust preselector trimmer C_D for maximum volume. As soon as you note a deflection of the meter while using the *V* range, use the meter as a visual tuning indicator, switching to higher voltage ranges as necessary. You will find visual tuning far more accurate than aural tuning, but will have to use aural tuning at the beginning in order to find the station.

If you find it necessary to set preselector trimmer C_D two turns or more off from maximum capacity in order to secure maximum volume, you have an undesirable condition in which a harmonic of the oscillator is beating with some station to give an i.f. value. In this case, readjust oscillator trimmer C_C to another setting at which a station is heard, adjust it for maximum volume, then adjust C_D for maximum volume.

i. Adjust i.f. primary trimmer C_P carefully now for maximum volume, using a non-metallic screwdriver. This screwdriver can be made from a stick of hard wood about 1/4 inch in diameter, sharpened at one end to the shape of a screwdriver blade. The handle of an old toothbrush can be used for this same purpose; simply cut or file the small end so it will fit in the slot of a trimmer adjusting screw.

j. Adjust i.f. secondary trimmer C_S for maximum output. If headphone volume becomes too loud or becomes distorted, reduce the a.f. voltage by rotating the 250,000-ohm potentiometer counter-clockwise. Finally, adjust i.f. trimmer C_B for maximum output.

The only trimmer which requires the use of the non-metallic screwdriver is i.f. primary trimmer C_P; this trimmer is at a high r.f. potential, and hence body capacity applied through a metallic screwdriver would make accurate adjustments difficult.

k. Try tuning in several other stations having frequencies in the range between 550 kc. and 1200 kc. To tune in a new station, first adjust oscillator trimmer C_C for maximum output on the new station, then readjust preselector trimmer C_D for maximum output. Do not change the i.f. trimmer settings once they have been made according to instructions in the preceding steps.

Broadcast band stations higher than 1200 kc. cannot be tuned in by the preselector trimmer. However, if sufficiently strong, such signals will come through provided the trimmer C_D is opened three full turns, and the oscillator trimmer is properly tuned.

Discussion: Although the test which you made in Experiment 59 showed that your superheterodyne receiver circuits had correct continuity to the plate and cathode respectively of the

power pack, and showed also that the tube electrodes had correct d.c. voltages, the signal circuits were very likely out of alignment, preventing reception of programs. The i.f. amplifier system must be aligned to the selected i.f. value for the receiver, and trimmers C_C and C_D must be tuned for reception of the desired station.

In this experiment, we go through the procedure for aligning the i.f. system and tuning in a station. The alignment procedure we employ in this experiment is somewhat different from that which would be used in a regular radio servicing job, for we depend upon the signal from a local or nearby radio station rather than upon the signal produced by a calibrated signal generator.

If you are using a fairly long aerial, you may encounter the condition whereby the signal becomes extremely loud and distorts when you attempt to tune in a powerful local station, with the distortion continuing even though you lower the setting of the volume control potentiometer. This is due to excessive signal strength at the grid input circuit of the 6SJ7GT oscillator-mixer-first detector tube, and is remedied simply by using a shorter antenna.

Remember that once you have aligned the i.f. amplifier section of your receiver, there are only three controls which will need adjustment. Use the 250,000-ohm potentiometer on *CHASSIS B* as an ordinary volume control, to regulate headphone volume to a comfortable level. Tune in a desired station with oscillator trimmer condenser C_C, then complete the tuning process by adjusting preselector trimmer C_D for maximum volume.

In a commercial receiver, a two-gang tuning condenser would replace C_C and C_D, to give single-dial tuning. Individual condensers such as we use serve to illustrate the principles of tuning more clearly, however. Actually, the individual condensers correspond exactly to those employed in radio receivers employing electric automatic push-button tuners; in these sets, the pair of trimmers assigned to each station must be adjusted exactly as you adjust C_C and C_D. Your superheterodyne receiver thus gives you actual practical experience in setting up the buttons of an automatic tuning receiver to desired stations.

Instructions for Report Statement No. 60. When an initial analysis of a defective receiver fails to reveal the nature of the trouble, the conventional servicing technique involves isolating the defect to a particular section of the receiver, locating the defective stage, then checking the defective stage with an ohmmeter to locate the defective part. There is one simple test, however, which enables you to determine definitely whether the defect is in the detector-a.f. amplifier system or is in the r.f. system.

When the r.f. system in a receiver is operating properly, the reception of a broadcast station signal will produce a d.c. voltage across the diode load resistor; this voltage is employed as the a.v.c. voltage in the majority of modern receivers. If the r.f. section is dead, this a.v.c. voltage will not exist.

For this report statement, you are to duplicate the symptom of weak reception while measuring the a.v.c. voltage. Shorting a few turns in one of the i.f. coils will do this, and is a condition actually encountered in radio work. Therefore, solder a short length of hook-up wire to the *gray* terminal of the *S.G.* coil, and arrange this wire so that you can readily make contact with it to the *yellow* terminal of the *S.G.* coil, thereby shorting out winding L_3.

Now connect the N.R.I. Tester to measure the d.c. voltage across a.v.c. filter condenser C_3 (black clip on *12* of *CHASSIS B*, red clip on chassis). You are now measuring the a.v.c. voltage which is applied to the input of the i.f. amplifier tube. Tune the receiver to a local broadcast station, listen to the program in the headphone, note the volume level, and note the a.v.c. voltage value as indicated by the N.R.I. Tester. Now connect the *gray* and *yellow* terminals of the *S.G.* coil together so as to short out winding L_3, while watching the meter and listening to the headphone. With the coil shorted, retune i.f. trimmer C_B for maximum output, noting the direction in which you have to rotate this trimmer condenser adjusting screw to do this, then answer Report Statement No. 60.

After completing an experiment and carrying out the instructions at the end, fill in the information asked for in the corresponding report statement on the next page or make a check mark like this √ *with* pencil in the box *following* what you consider to be the correct answer. PLACE NAME, ADDRESS AND STUDENT NUMBER ON BACK OF LAST PAGE.