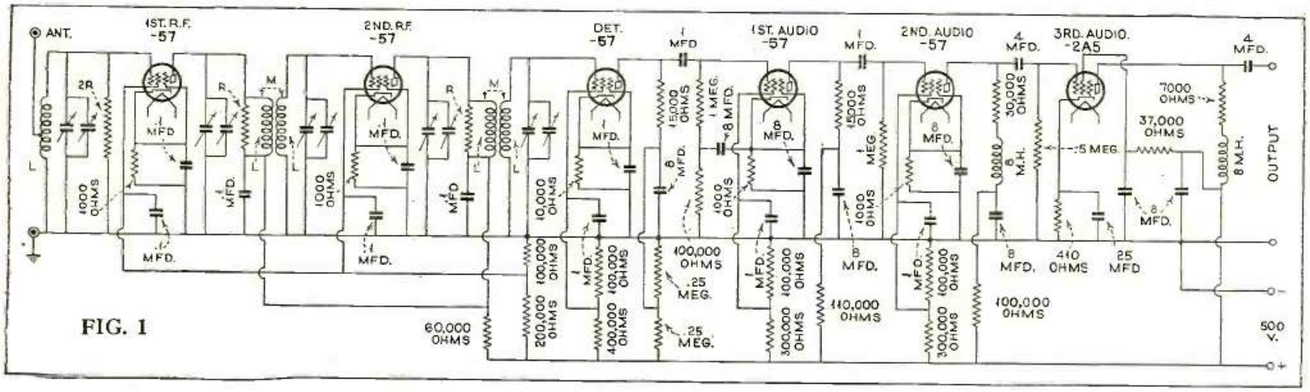


FIG. 1

TELEVISION

(Receiver Design)

In concluding the series on the use of cathode-ray tubes, the authors add an article on the design of the radio television receiver proper

J. M. Hollywood, M. P. Wilder

SINCE many are not familiar with the radio receiver proper as used in television either for cathode-ray tube reception or mechanical scanning methods, it was thought desirable to add an article on that subject to this series, even though not directly connected with the subject of cathode-ray tubes.

An ordinary broadcast receiver has three main functions. One is to convert modulated radio-frequency current into direct current varying in accordance with the sound picked up by the microphone at the transmitting station; this is the process of detection. The second is to provide enough amplification so that the small amount of energy picked up by the aerial can operate a loudspeaker. The third is to provide radio-frequency selectivity such that the desired signal can be separated from others. The loudspeaker then serves a fourth function of converting electrical energy into a reproduction of the original sound.

This is not much different from the process in television reception. There the loudspeaker is replaced by apparatus which converts electrical variations into light variations, together with scanning apparatus which makes a point of light trace out a whole picture. For cathode-ray tube reception, this apparatus was described in previous articles of the series.

The television receiver proper has the same functions as a broadcast receiver; namely, detection, amplification, and frequency selection. The difference between the two classes of receivers lies in the fact that a broadcast receiver must cover a range of modulation frequencies from 20 to 5000 cycles, and separate stations 10 kc. apart in frequency; but a television receiver must cover a range of modulation frequencies from a fraction of a cycle to 100,000 cycles or so, and separate stations over 200 kc. apart in frequency, for good 60-line pictures.

This means that in television receivers the radio-frequency tuning must be much broader, the "audio" frequency amplifier must have a much flatter frequency response curve, and the detector must have much better output for high modulation frequencies than in the case of a broadcast receiver.

The circuit diagram of Figure 1 shows a receiver that fulfills these conditions. This circuit does not differ at first glance from that of a tuned r.f. broadcast receiver using a resistance-coupled audio amplifier. The difference lies in the choice of values for the circuit elements. In the audio amplifier, for example, the coupling resistances are much smaller than usual, to reduce the relative effect of the stray capacities by-passing the coupling resistors. This makes the frequency response flat to very high modulation frequencies, at the cost of reduced gain per tube. The audio amplifier shown is designed somewhat like the high-gain amplifier described in the March issue. It uses two type -57 tubes for voltage amplification and a 2A5 power tube.

The 2A5 power tube is used, not because of the power delivered, but because the small load resistance required reduces the by-passing effect of the stray capacity of the lead to the cathode-ray tube grid, which may therefore be moderately long. This lead should not run through a cable, but as much in the open as possible, and should not be over five feet long. If the cathode-ray tube is to be used far from the receiver, it would be better to use a 2A3 instead of a 2A5, and use a load resistance in its plate circuit of 2500 ohms instead of 7000 ohms.

With three audio stages and a plate detector, an increase in radio-frequency input will cause the ungrounded output terminal to become more positive. If this terminal is used to apply voltage to the modulating grid of a cathode-ray tube, a positive picture will result for most television signals. The transmitting station generally increases its output on the bright parts of the picture, but if it does the opposite, the phase of the cathode-ray tube grid voltage at the receiver must be reversed or a negative picture will result. This reversal is best accomplished by adding an extra resistance-coupled audio stage with little or no amplification; for instance, a -56 or

DYNATRON TEST OSCILLATOR

Figure 2. This oscillator circuit is employed, as described in the text, to measure the inductance and mutual inductance values of the coils required, simplifying the cut and try method of determining proper values

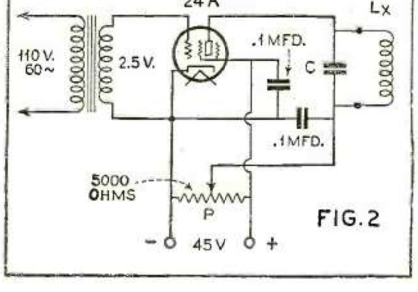


FIG. 2

EFFECT OF INSUFFICIENT DAMPING

Figure 3. This is the double hump characteristic obtained in normal, closely coupled r.f. tuned circuits

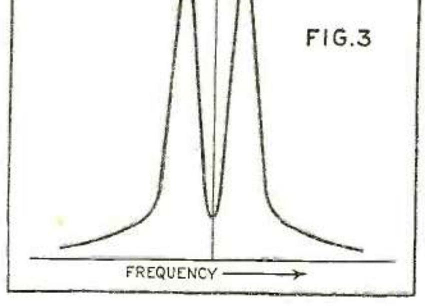


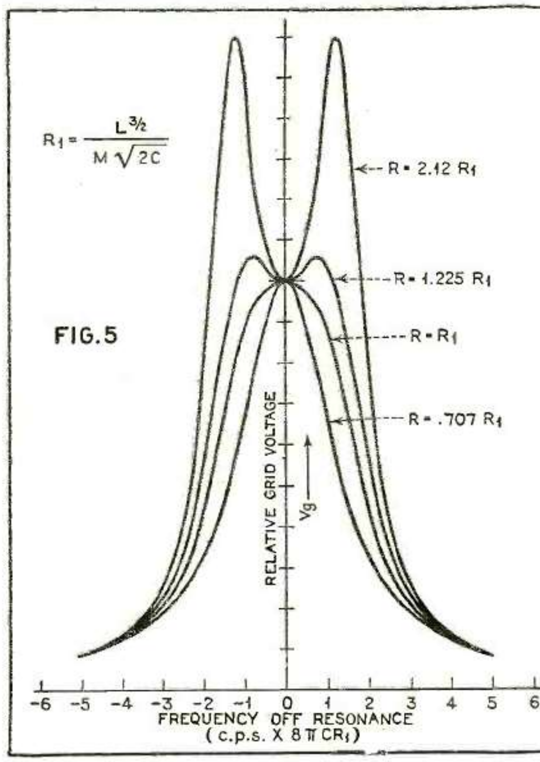
FIG. 3

a -57 tube with a 1000-ohm coupling resistor.

Any type of detector can be used, but resistors across which audio-frequency voltage is to be developed must not be by-passed seriously by any capacitance, or if they are, the resistance must be reduced accordingly. The product of resistance in ohms and capacitance in mfds. should be kept under one-half. For grid leak and condenser detection, the grid leak must be so small that this method is not very practical. Plate detection may be used, with plate-circuit resistance values similar to those used in the audio amplifier. Diode or duo-diode detection is also good, if the condenser by-passing the diode load resistor is under 20 mmfd. and the resistor about 25,000 ohms. Incidentally, if grid leak or duo-diode-triode, etc., detection is used instead of plate detection, the phase of the "audio" voltage is reversed. Plate detection was chosen for the diagram given, because it is simple and reliable. No radio-frequency filters are used in the detector output, because they by-pass the higher modulation frequencies too badly.

The most striking difference between a television receiver and a sound receiver lies in the radio-frequency amplifier. Modulation frequencies of about 100,000 cycles must be passed, requiring a radio-frequency band width of almost 200 kc. for good 60-line pictures. In the diagram shown, this band width is provided by means of tuned, coupled circuits which act much like band-pass filters. When two tuned circuits without resistance are coupled together as the coupling agent between tubes, the voltage delivered by the combination is not a maximum at resonance, but instead the resonance curve shows (two) large peaks of voltage occurring at frequencies on each side of the resonance frequency, separated from it by a frequency proportional to the degree of coupling and to the resonant frequency. Figure 3 illustrates such a case. That is to say, the ratio of frequency separation between the two peaks to the average frequency is proportional to the coupling coefficient. The separation will in a way determine the band width obtained; the ratio above is small for a broadcast receiver and the coupling is loose, but it is larger for television work and rather tight coupling is used.

It is clear, of course, that such a sharp, double-peaked resonance curve would be totally unsuited for band-pass action, which in the ideal case would give constant output over a 400 kc. range and zero at all other frequencies. (A 400 kc. band width is to be used in this receiver, which should give good pictures of more than 60 lines.) However, when resistance is added to the circuit—for example, by the shunt resistors R in the diagram—the resonance curve is changed. The peaks are greatly reduced in size, but the response at the resonant frequency is not much reduced, so that the resonance curve can be made such as to give an almost constant output over the desired frequency range. The value of shunt resistance that will accomplish this becomes smaller as the desired frequency range and the coupling are made larger. It also becomes smaller as the tuning capacity is made larger. Since the amplification will depend largely on the size of this resistance, much more amplification can be obtained if the tuning capacity is kept small and the shunt resistor made correspondingly large. It can be seen that the gain per stage must be reduced as the modulation-frequency range is made greater, which was also the case for the audio amplifier. Figure 5 shows the effect of varying the shunt resistance on the shape of the resonance curve; Figure 4 shows the effect of changing the coupling.

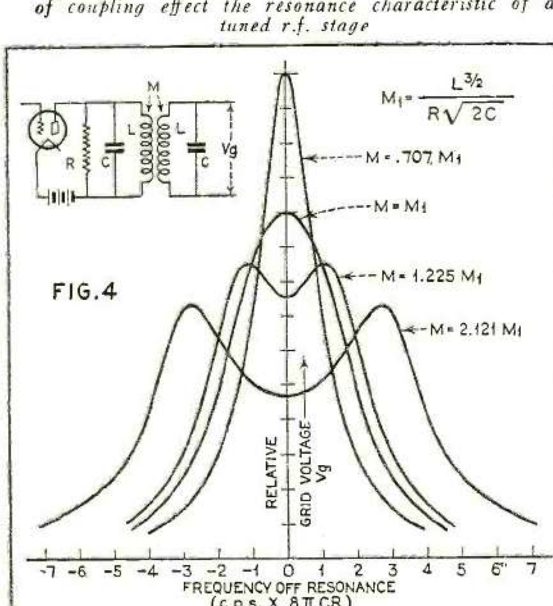


SHAPING THE RESPONSE CURVE

Figure 5. By selecting the proper shunt resistors, as indicated at R (Figure 1), the double hump effect is eliminated and a broadly peaked characteristic suitable for television tuner circuits is obtained

R.F. COUPLING CHARACTERISTICS

Figure 4. These curves show how different degrees of coupling effect the resonance characteristic of a tuned r.f. stage



The tuned radio-frequency receiver shown was selected for this article because it is simple and yet illustrates the essential points in good television receiver design. It suffers from one notable defect; that is, if the tuned coupled circuits are designed for band-pass operation at one carrier frequency, the resonance curve will not be very good when a different carrier frequency is to be tuned in. It would therefore be advisable to use a superheterodyne instead of a t.r.f. receiver, because the band-pass action could then be confined chiefly to the intermediate-frequency amplifier, which could be adjusted carefully for best results and left alone. The superheterodyne also has the advantage that with a coil-switching arrangement it could be made suitable for either the 1500 to 3000 kc. television signals or the experimental transmissions sent on something like 60,000 kc. However, those readers who are sufficiently familiar with receiver construction to make a successful superheterodyne will probably be able to apply the principles involved in the t.r.f. receiver to the superheterodyne. No new problem is involved, except that the oscillator and first detector should be suitable for use where the carrier frequency and oscillator frequency are widely separated. A pentagrid converter (2A7, for example) would be quite satisfactory. A good choice of intermediate frequency would be 6000 kc. For the signals between 1500 and 3000 kc., the oscillator frequency could be 7500 to 9000 kc., and for the signals around 60,000 kc. the oscillator frequency can be about 54,000 kc.

Suitable values of the circuit constants for a carrier frequency of 2800 kc., with the t.r.f. receiver shown in Figure 1, are as follows: All tuning condensers are to be of 100 mmfd. capacity, ganged, with small trimmers. The inductances (*Cont'd on page* 702)

Now apply a thin coat of floor wax (not liquid wax), and after a half hour rub it to a polish. Do this three or four times, and you can almost swear your case is made of solid ebony.

The model illustrated is equipped with a carrying lanyard, by which the aid is slung over the shoulder like a camera. This is a piece of ½ inch black grosgrain ribbon, fastened to the sides of the case with screw eyes and ¾ inch loose-leaf notebook rings. If preferred a leather or metal handle could be attached.

Now mount all parts in the outside case, wiring according to the diagram in Figure 2 as you go along, and soldering all contacts securely.

The headphone used by the writer was one from a set of "Cannon Ball Dixies." Any light weight receiver rated at 1000 ohms or higher will do. The Trimm "Featherweight" is excellent but if lower cost is imperative there are the "Erpee" and "Acme" headphones, both of which are extremely light and inexpensive.

In operating the instrument, do not advance the filament rheostat any more than is necessary, and always be careful to shut it off entirely when the aid is not in use. No volume control is included, other than that provided by the filament rheostat and this is only partially effective. The constructor may wish to improve on this feature and can do so by connecting a 50,000 ohm potentiometer across the transformer secondary, and then connecting the grid of the tube to the arm of the potentiometer.

Parts List

M—Microphone as described in text
R—Carter type M-30-S midget 30-ohm rheostat with switch
T—Polymet type TA-737 microphone transformer
VT—Type -30 vacuum tube
1 tubular flashlight for A battery case as described in text
2 tip jacks
7 four-prong wafer socket
1 case as described in text
2 Eveready No. 950 unit cells
8 Eveready 3-volt "pen-light" batteries
1 lightweight 1000-ohm or 2000-ohm headphone with cord and headband
Wire, screws, sheet metal, small mounting angles, etc.

Television

(Continued from page 665)

L should tune to 2800 kc. with about 10 mmfd. of the condenser capacity in use. Assuming 10 mmfd. of stray capacity or a total of 20 mmfd., L should be .16 millihenry. The coupling coefficient should be .143, and M .023 millihenry. R should be 10,000 ohms. Amplification per stage will be about 24 times. The band width should be 400 kc. The circuit will tune to about 1500 kc. minimum, but the resonance curve will be rather badly peaked on the lower carrier frequencies.

To cover the same range of carrier frequencies, but with best operation on 2100 kc., make L .16 millihenry as before, to tune to 2100 kc. with about 26 mfd. of the tuning condenser in use (assuming 10 mmfd. stray capacity). Make the coupling coefficient .191, and M .031 millihenry. R should be 6000 ohms. The gain per stage will be about 14 times.

For the intermediate-frequency amplifier of a superheterodyne operating at 6000 kc., use 20 mmfd. adjustable condensers for the permanent tuning. Make L .035 millihenry, the coupling coefficient .094, and M .0032 millihenry. R should be 10,000 ohms and the gain per stage about 17 times.

A good way of measuring the values of L and M, so that they may be adjusted by the cut-and-try method, is to use a dynatron oscillator, a calibrated broadcast receiver, and an accurately known capacitance. The dynatron oscillator circuit is given in Figure 2. The potentiometer P is adjusted for maximum oscillation. The capacitance C can be a 150 or 250 mfd. variable or fixed condenser for which the capacity is fairly accurately known. The frequency determined by L_x and C can be found by turning the dial of the broadcast receiver, with the dynatron in its vicinity and the aerial disconnected. A hum will be heard at one or more points on the dial, unless the coil L_x is too small to give an oscillation frequency below 1500 kc. The frequencies at which the hum is heard will be the fundamental frequency or that frequency multiplied by an integral number. Note all frequencies at which the hum is heard; the average frequency separation between them will be the fundamental frequency, or if only one point occurs, it should be the fundamental, except where between 1100 and 1000 kc., in which case it may be a second harmonic. For example, 375 kc. oscillations would be heard at 750, 1125 and 1500 kc., and 800 kc. oscillations would be heard only at 800 kc. on the usual broadcast receiver. The value of L_x in millihenries is given by

$$\left(\frac{25{,}300{,}000}{f^2 \times C}\right)$$

where f is the frequency in kc. and C the capacity in micromicrofarads.

To measure L, M and the coupling coefficient k most easily, connect the two coils of the r.f. or i.f. transformer in series, first in opposition and then so as to aid each other, using the combination as L_x in the dynatron oscillator. L_x will then be first $2(L - M)$ and then $2(L + M)$. Measure the frequencies obtained; call them f_1 and f_2. Then the values of L, M and the coupling coefficient k will be given by the following formulas:

$$L = \frac{25{,}300{,}000}{4C}\left(\frac{1}{f_2^2} + \frac{1}{f_1^2}\right)$$

$$M = \frac{25{,}300{,}000}{4C}\left(\frac{1}{f_2^2} - \frac{1}{f_1^2}\right)$$

$$k = 2\left(\frac{f_1 - f_2}{f_1 + f_2}\right) \text{ approximately}$$

The formula for the coefficient of coupling does not require knowledge of the condenser capacity. The inductance values above are in millihenries when C is in mmfd. and frequency kilocycles.

One other matter worth mentioning is the antenna coupling system. The method shown in Figure 1 allows ganging of all tuning condensers without having too much detuning effect from the aerial, and the shunt resistance (2R) can be made accurately twice the value of that used on the double tuned circuits, which will give proper results. Since damping is introduced artificially by the shunt resistance, the same damping effect and more output could be obtained by using more antenna coupling and omitting the resistor. This is not recommended, because the damping and tuning will change whenever the aerial used is changed, and ganged tuning will not be possible.

It is to be hoped that this series of articles has given its readers better familiarity with the cathode-ray tube and its uses, together with some practical information on its application.