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Television Receivers

PART 3

By the Engineering Department, Aerovox Corporation

I.F.-AMPLIFIERS

THE circuits of the picture-i.f. amplifiers may look quite unfamiliar to servicemen and others who have worked only with ordinary broadcast receivers. The i.f.-amplifier in a television receiver consists of two distinct amplifiers: the sound-i.f. amplifier and the picture-i.f. amplifier. They are preceded by a network which serves to separate the two signals.

When a.v.c. is used in the picture-i.f. amplifier as well as in the sound amplifier it may then be a separate a.v.c. system, or, the a.v.c. system of the sound-i.f. amplifier may control some of the picture-i.f. stages while the other stages are manually controlled. In the smaller and less expensive receivers, the picture-i.f. amplifier has no a.v.c. and the manual sensitivity control is called "contrast control".

THE SOUND-I.F. AMPLIFIER

There is practically nothing new in the sound-i.f. amplifier. it is of the usual construction employing double-tuned circuits which are deliberately made rather broad so as to make the tuning less critical and to insure good quality. The RMA standard frequency for the sound-i.f. amplifier is 8.25 mc. In some cases this frequency may be changed again to 455 kc. making this part of the receiver a double superheterodyne.

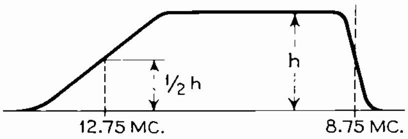

Fig. 1

Those who make their own television receivers might use an existing all-wave set for the sound reception by tuning it to 8.25 mc. and coupling it to the first detector of the television receiver. If this is done, care should be taken not to feed the signal from one converter into the next; there should be at least one 8.25 mc. amplifier stage in between. In general, the use of the double super is not advised. Such a circuit is subject to complications due to the interaction of the two oscillators; the results are numerous birdies and "ghost signals". Only extreme care in the shielding and design of the oscillators will prevent this difficulty.

The alignment of the sound i.f. amplifier should not offer any difficulties to those who are familiar with present-day alignment procedure.

THE PICTURE-I.F. AMPLIFIER

It was explained in Part I that the picture carrier or "video"-carrier has been modulated normally at the transmitter and then has a part of one sideband removed. The radiated signal then consists of the carrier, a double-sideband for the lower "video-frequencies" and a single-sideband for the higher video-frequencies. If such a signal were passed by the i.f.-amplifier unchanged and rectified, the lower video-frequencies would arrive twice as strong as the higher ones. Therefore, the i.f. response curve is to have a special shape which corrects this trouble. The RMA standard curve is shown in Figure 1. Note that the high-frequency end of the curve is sloping and that the carrier falls at a point where the response is one-half of the peak value. The two sidebands of the lower video-frequencies and the carrier have been cut so that their combined effect is equal to that of the single-sideband at the higher frequencies.

At the low-frequency end of the i.f. response curve a sharp cut-off is desirable because the sound-carrier of 8.25 mc. must not pass through the picture channel and yet the sidebands down to 8.75 mc., which represent the highest video-frequencies (fine detail in the picture), should be passed. The

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wide-band amplifier must generally be supplied with special trap circuits to keep the sound-carrier out of the picture-channel.

Taking the 50-56 mc. channel as an example, the picture-carrier is at 51.25 mc., the sound-carrier at 55.75 mc. After beating these carriers with the oscillator (64 mc.), these become 12.75 and 8.25 mc. respectively. The sound-carrier of the lower channel, 44-50 mc. is at 49.75 mc. which becomes 14.25 mc. in the i.f.-amplifier. This carrier may sometimes become troublesome and many receivers include trap circuits in the picture-i.f. amplifier to eliminate it.

The picture-i.f. amplifier generally consists of several stages; some are straight band-pass stages while some band-pass stages each have one trap circuit added.

BAND-PASS AMPLIFIER STAGES

Each amplifier stage consists of an amplifier tube plus a network coupling it to the next tube. For reasons which shall become clear later, the amplifier tube must be one of the high-mutual-conductance type such as the 1851, 1852, 1853, 1231 or 1232. The coupling circuit provides the band-pass properties. Some engineers prefer to use the filter theory for calculating and designing the circuit. The result is usually a configuration which is totally unlike the familiar coupling circuits. One may also employ the customary overcoupled circuits. Overcouple them still more to make them broad enough and conect resistors across them to lower the double peaks. This type of circuit can be shown to be equivalent to a T-network or Pi-network such as the filter theory would provide.

The following is a brief review of the behavior of overcoupled circuits with design equations included. Those who are not mathematically inclined may skip the equations and still derive a comprehensive understanding of coupled circuits.

Assume two tuned circuits, individually tuned to the same frequency and coupled inductively. Let one of the circuits, the primary, be excited from a suitable generator, such as an amplifier tube (see Figure 2). Due to the inductive coupling, the current in the coil L_1 will induce an e.m.f. in the secondary (L_2). The magnitude of this e.m.f. is

$$E_2 = -j\omega M I_1 \qquad (1)$$

and it lags 90 degrees behind the primary current. This e.m.f. will cause a current to flow in the secondary and when the secondary is tuned to the signal frequency, the impedance of the secondary is a pure resistance. The secondary current, I_2, is therefore in phase with the induced e.m.f., E_2.

$$I_2 = \frac{E_2}{R_2} \qquad (2)$$

This secondary current again induces an e.m.f. into the primary which is opposite in phase to the primary current. The net result of the presence of the secondary is the same as if a resistance had been added to the primary circuit. The magnitude of this resistance is

$$\frac{(\omega M)^2}{R_2} \qquad (3)$$

If the secondary had not been tuned to the frequency of the signal, but had too much inductance, the secondary current would have lagged behind the induced e.m.f. in the secondary and the e.m.f. induced in the primary would have lagged less than 180 degrees behind the primary current. The effect of the secondary on the primary would then be the same as if a resistance and a capacitive reactance had been added to the primary. Similarly, had the secondary had too much capacitive reactance, it would have reflected back on the primary as a resistance and an inductive reactance. The magnitude of this "coupled impedance" is

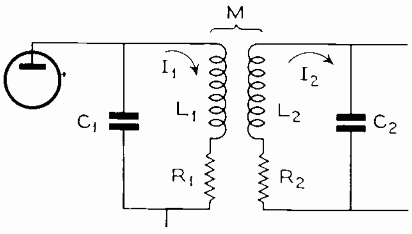
$$\frac{(\omega M)^2}{Z_2} \qquad (4)$$

Therefore we see that a correctly tuned secondary does not alter the tuning of the primary but a detuned secondary has the effect of detuning the primary in the opposite direction.

The coupling between two inductances is indicated by a coefficient k. When all the magnetic flux of the primary circuit is linked with all of the magnetic flux of the secondary, then k equals unity or the coupling is 100%. In general

$$k = \frac{M}{\sqrt{L_1 L_2}} \qquad (5)$$

Let us gradually increase the coupling in the circuit of Figure 2 by increasing the value of M (the mutual inductance) and let us observe the effect on the shape of the resonance curve as it would be seen on an oscillograph and wobbulator. The circuits are still individually tuned to the same frequency.



$$Q_1 = \frac{\omega L_1}{R_1} \qquad Q_2 = \frac{\omega L_2}{R_2}$$

$$Z_2 = \sqrt{R_2^2 + \left(\omega L_2 - \frac{1}{\omega C_2}\right)^2}$$

$$\omega = 2\pi f$$

Fig. 2

When M is very small and we have very loose coupling, the voltage across the secondary condenser has a single peak and is very sharp. This condition is known as "insufficient coupling" because the voltage across the secondary condenser is not as high as it might be.

When the coupling is now further increased, the height of the resonance curve grows until we come to a condition called "critical coupling". At this point, maximum energy is transferred from primary to secondary and it is the point of maximum response where there is still a single peak. At critical coupling

$$\omega M = \sqrt{R_1 R_2} \qquad (6)$$

The coupling still can be increased but the response at resonance does not increase any more. The curve now becomes double peaked; one peak is below and one above the resonant frequency. The peaks have moved farther apart when the coupling is made tighter; they become higher when the coils have a high Q (have little resistance) and lower when the Q is low.

$$Q = \frac{2\pi f L}{R} \qquad (7)$$

In the application of the double-peaked response curve for picture i.f. amplifiers, the peaks must first be brought far enough apart and then they must be lowered by making the circuits less efficient (placing resistance in series or in parallel with them) until, at a critical value of Q, the response curve is nearly flat.

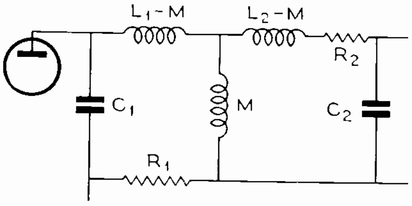


Fig. 3

When we call a the ratio of the response-at-a-peak to the response-at-the-valley of the response curve, then

$$K\sqrt{Q_1Q_2}=a+\sqrt{a^2-1} \qquad (8)$$

and the frequencies of the two peaks or the band-width is given by

$$\frac{f}{f_1}=\frac{f_2}{f}=\sqrt{\frac{1-\frac{1}{2Q_1Q_2}\pm\sqrt{K^2-\frac{1}{Q_1Q_2}}}{1-K^2}} \qquad (9)$$

where f is the frequency at resonance (at the valley), f_1 the frequency at the low-frequency peak, f_2 the frequency at the high-frequency peak.

$$f^2=f_1f_2 \qquad (10)$$

When the two circuits are not tuned to the same frequency the peaks will not be equally high. If one circuit is being mistuned more and more, one peak becomes lower and moves farther away until it is no longer visible. The remaining peak then looks like the sharp peak obtained in critical coupling. In aligning circuits wth the wobbulator this condition must not be confused with correct alignment.

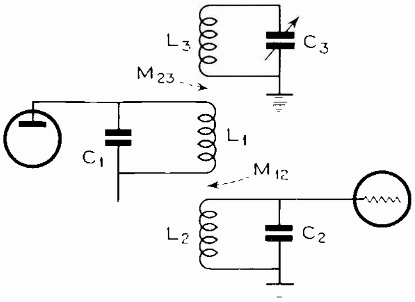


Fig. 4

The equations 1 - 10 now give the necessary data for calculating the required band-pass circuit. One additional equation is needed to find the gain per stage with any given tube. The gain is:

$$\text{Gain}=G_m\pi f\sqrt{L_1L_2Q_1Q_2} \qquad (11)$$

Here it become clear that the gain is lowered when the Q is lowered. Since unusually low values of Q are needed, there would not be any gain left if the ordinary i.f.-pentodes were used. Tubes with a large mutual conductance (Gm) compensate somewhat for the loss in gain due to low Q. It is also desirable to make L_1 and L_2 as large as possible and the tuning condensers as small as possible. The practice is now to employ the tube capacity and the stray wiring capacity as C_1 and C_2 and not to use any condenser at all. The tuning must then be adjusted by variable coils equipped with movable iron cores.

In order to figure the necessary constants for a coupling circuit one may proceed as follows: Measure the value of C_1 and C_2 in the set by means of a Q-meter, or else assume a value somewhat too high and make up for it by employing small trimmers. Assume the required values of f_1 and f_2 and decide an a value for a. Then calculate f by equation 10 and L_1 and L_2 from the usual equation for a resonant circuit. Solving 8 and 9 simultaneously gives values for k and $\sqrt{Q_1Q_2}$. Then M is found from 5 and the gain from 11. The answers for one case were:

$C_1 = 20$ micromicrofarads
$C_2 = 25$ micromicrofarads
$L_1 = 12.8$ microhenries
$L_2 = 10.4$ microhenries
$M = 3.4$ microhenries
$\sqrt{Q_1Q_2} = 7.4$

It can be shown that the circuit of Figure 2 is equivalent to the circuit of Figure 3 where the values of the units are given in terms of the constants in Figure 2. This circuit may be more convenient since it is easier to adjust L_1 and L_2 independently. The RCA television receiver employs a circuit similar to this.

Band-pass stages incorporating a trap circuit can be formed from the circuit of Figure 2 by addition of the absorption circuit whch is tuned to the frequency to be eliminated and critically coupled to the plate circuit (Figure 4). Its equivalent circuit is shown in Figure 5.

THE SEPARATION NETWORK

The sound and picture i.f. may simply be coupled to the primary, one secondary may be on one side and one on the other side of the primary. Some receivers are equipped with special circuits which are variations of this. These should be easily understood.

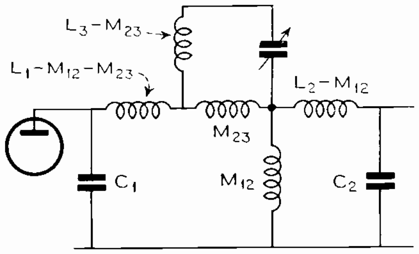
ALIGNMENT

The only convenient way of aligning the broad-band amplifier is by means of a wide-sweep wobbulator. The practice is now to employ an absorption circuit in the wobbulator which causes a nick in the trace at the frequency of the video carrier. This helps in adjusting the curve so that the nick falls half-way on the slope of the curve.

Those who do not possess a wobbulator may try the system of plotting the curve by the point-to-point system. This is laborious but it is the only alternative to be suggested at present.

A.V.C. CIRCUITS

In some receivers the picture i.f. amplifier has its own a.v.c. circuit. This is quite a different form from the circuits hitherto employed. Due to the peculiar system of modulation employed in television, the a.v.c. voltage should be proportional to the peak values of the modulated wave and not to the average value as in sound transmission. The peaks of the synchonizing impulses represent the highest power transmitted and this level does not vary with the brilliance of the picture. Therefore the a.v.c. voltage must be controlled by these peaks, for it would not do to have the control voltage vary with the brilliance of the picture.



The a.v.c. circuit consists of a "peak voltmeter" connected across the detector load. It must, however, draw no current from the detector load. So the peak voltmeter is an over-biased tube with the load in the cathode circuit (Figure 6). The highest impulses of the signal cause some current to flow in the plate circuit of the tube. These impulses charge condenser C_1 which is so proportioned that the charge cannot leak off in time through R_1. Thus the voltage across C_1 is determined by the peak value of the signal.

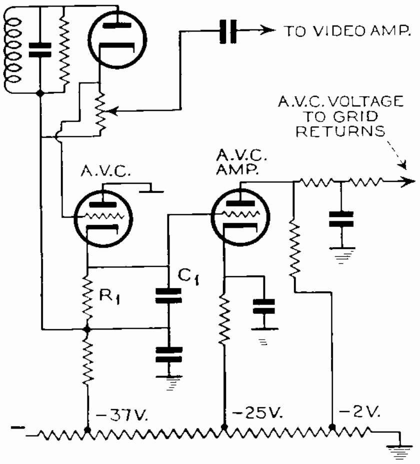


Fig. 6

In the RCA receiver TRK9, an amplifier tube is used which inverts the control voltage as well as amplifies it. This is necessary to obtain a voltage of the proper polarity for control of the amplifier grids. Figure 6 shows this circuit in simplified form. It is of course necessary to return cathodes and grids to points on the voltage divider which are negative with respect to the chassis so as to obtain a negative control voltage.

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