Television reception with the superheterodyne

By R. William Tanner

HERETOFORE it has been almost impossible to bring in television signals on a superheterodyne with even fair pictorial detail. A number of manufacturers have brought out supers claiming that these receivers will tune in television stations. To be sure, ANY short-wave receiver will do this but the question is: "Will the resulting pictures have good detail?" The answer is: "No, unless the receiver is designed especially for such use." When this is done, it is of little or no value for other services.

The reason for this is easily understood when it is considered that the highest audio-frequency encountered in present-day television practice is slightly higher than 40,000 cycles with 60 line scanning.

It is readily apparent then that a receiver wherein the tuned circuits are capable of passing a band of frequencies 80 kc. wide without sideband clipping, would hardly suffice for broadcast reception considering the fact that broadcast stations are allotted channels 10 kc. apart.

The problems of television superheterodyne design are many and varied. Sensitivity is merely a matter of sufficient number of intermediate-frequency stages. To bring about the condition of 80 kc. selectivity, some drastic work on the tuned circuits is required. Band-pass filters, properly constructed, will, of course, solve this problem, but are not an absolute necessity.

Choice of Intermediate Frequency

The choice of intermediate frequency and the elimination of image frequency interference assume no mean proportions. Also, considerable thought must be expended towards reducing regeneration in the i-f. stages and second detector to a negligible quantity.

There are two factors upon which depends how high or how low the intermediate frequency may be. The high limit is determined, not by the gain per stage, because high orders of amplification are possible from 2,000 kc. on down, but by the fact that the second and third harmonics of the intermediate frequency must fall outside of the television band. It has been found that these harmonics will generally appear with sufficient intensity to cause serious interference if allowed to feed back into the first detector. At first thought, it would seem simple enough to filter out these harmonics appearing in the second detector plate circuit, but, actually this is extremely difficult to accomplish.

The low limit is determined by the problem of image frequency selectivity; that is, of keeping the second signal, which a given oscillator setting will heterodyne to the intermediate frequency, far enough from the desired signal so that great selectivity will not be needed ahead of the first detector.

Image frequency interference, as it is termed today, is the old familiar repeat spot problem. Obviously, there are two oscillator frequencies which will serve to heterodyne a signal to the intermediate frequency, these being separated by twice the intermediate frequency. Also one oscillator setting will serve to heterodyne two signals to the intermediate frequency. To eliminate this type of interference, it is essential that the selectivity of the tuned circuits preceding the first detector be sufficient to definitely suppress the unwanted signal.

If the intermediate frequency is too low, excessive selectivity of the first detector tuned circuits will be required which would mean greater complication in the construction as well as increased cost of production.

Image Frequency Interference

Even with the highest possible intermediate frequency, one tuned circuit ahead of the first detector is not sufficient to eliminate image frequency interference. At least two are necessary, the simplest and least expensive arrangement being in the form of a two section band-pass filter. Considerable research with all forms of supers has proven that this band-filter can be adjusted to pass a band much narrower than that required in the i-f. amplifier and still give good pictorial definition. This makes it possible to design the two sections for, let us say, 20 kc. selectivity which would enable the operator to tune out a television station operating on the next channel.

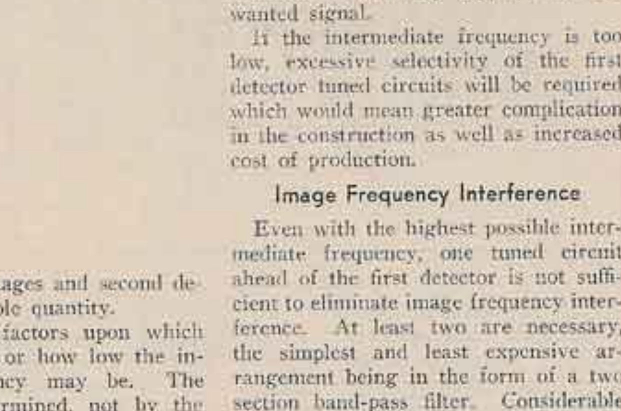

Fig. 1. Intermediate-frequency amplifier.

At the present time, the writer has a super in operation which uses regeneration in the first detector as well as a band filter. Here in Michigan it is practically impossible to bring in the east coast 60 hole stations when any of the Chicago 45 hole stations are on the air. Yet with the super just mentioned, by merely increasing first detector regeneration to a point where selectivity is sufficient, the Jenkins stations are brought in with fine detail and with no interference from Chicago. Increasing the regeneration up to the point of oscillation results in the noticeable decrease in pictorial detail but not to the extent that would be thought.

Considering all of the factors mentioned, together with much research work, it would seem that an intermediate frequency somewhere between 400

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Engineering details of the design of a superheterodyne receiver suitable for television.

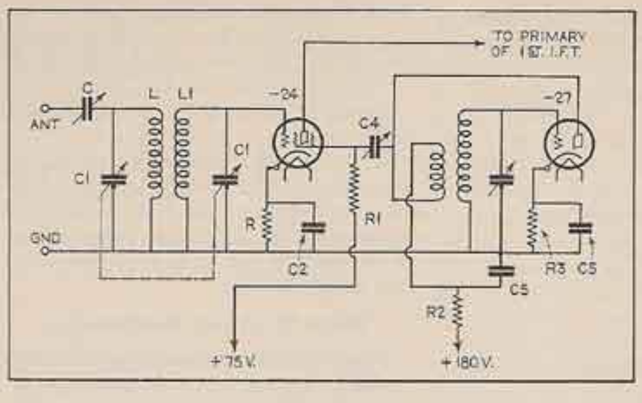


Fig. 2. Showing the use of a band-pass filter in the short-wave end for elimination of image frequency interference.

and 500 kc. would be ideal for a television superheterodyne. Harmonic interference cannot be bothersome and image frequency interference is reduced to a point where it can cause no trouble whatsoever.

The Amplifier

With the problem of intermediate frequency solved, it is an easy matter to design a two or three stage amplifier giving sufficient gain to work over comparatively long distances. It has been found that with more than three tuned stages, it is difficult to construct the amplifier to pass the required 80 kc. band without sideband clipping. Even with only two or three stages, loose coupling in the i-f. transformers must be avoided.

Sufficiently tight coupling cannot be obtained in any manner by employing small diameter winding forms. Neither can concentrated windings, such as honeycomb or layer wound coils, be used since in this case the coupling between primary and secondary would be reduced. Of course, it would be possible to employ tuned trap circuits in place of transformers but this increases the feedback problem and often results in motor-boating.

A diameter of approximately 2 inches is as small as can be used to provide a high degree of coupling. Small wire, 30 to 34 gage enamel, will result in a coil not too large for a compact set. Such transformers can be enclosed within copper or aluminum cans 3 inches to 4 inches in diameter.

By employing shunt capacities such as those used in present-day broadcast supers, the effect of the high degree of coupling in the transformers is partially ruined. Transformers should be worked as close as possible to the fundamental, therefore, the shunt tuning condensers should be between the limits of .00005 to .0001 mfd.

In Fig. 1 is depicted a schematic diagram of an ideal i-f. amplifier for a television superheterodyne. Type '51 variable-mu tubes are used in the i-f. stages and a '24 as a second detector. Regenerative effects are reduced to minimum by the generous use of by-pass condensers and r-f. chokes.

It will be noticed that a linear or bias type detector is employed which is not in strict accordance with the design of modern television receivers. There is a very good reason for this type of detector as will be explained.

Shielding

It is essential that the i-f. transformers and tubes be completely shielded to eliminate feedback, and generally the plate and grid leads as well. The latter precaution is overlooked in a great many of the modern broadcast and television receivers which results, to a certain degree, in regeneration and, quite frequently, oscillation.

The problem of the second detector plate by-pass and r-f. choke is a rather difficult one. Obviously, the r-f. currents in the plate circuit will not only increase the feedback in the i-f. amplifier but also cause distortion in the audio amplifier unless provided with a low resistance path to ground. At first thought it would seem possible to employ a relatively large capacity from plate to ground. However, if this capacity is much larger than .00015 mfd. some of the higher audio frequencies will not reach the audio amplifier, hence the latent pictorial details will not be present in the picture. A capacity of .00015 mfd. is far too small to by-pass frequencies as low as 400 to 500 kc. But as this cannot be increased a larger r-f. choke will have to be used. In some cases, two chokes connected in series will be needed.

The short-wave r-f. circuits will be discussed next. The necessity of plug-in coils is eliminated in a receiver designed for television reception since, as stated previously, such a receiver is of little use for other services due to its natural broad tuning qualities. The present television band is from 100 to 150 meters (3,000 to 2,000 kc.) and can be covered with small, compactly wound coils together with low-capacity tuning condensers. A preferred arrangement is shown in Fig. 2.

The band filter coils L and L1 are tuned by means of a two-gang condenser C1. The antenna is coupled to the first section through a capacity C. A screen grid '24 tube is employed as a detector. Bias detection is shown but grid-leak-condenser detection may be employed if desired. The two sections of the band filter should be wound side by side on the same form, the spacing between depending upon the degree of selectivity desired at this point.

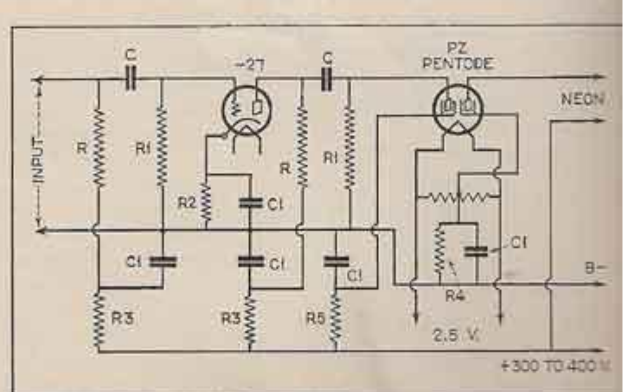
The Oscillator

The oscillator is of conventional design, the grid being biased to reduce the plate current. Energy is transferred to the first detector through a small capacity C4 connected from the detector screen grid to oscillator plate. The plate voltage is dropped to the required value by means of the resistor R2 which also functions as a radio frequency choke, thereby preventing coupling through the B supply.

It would seem rather unreasonable to construct a tuner and i-f. amplifier capable of passing the required band and then employ an audio amplifier which starts to cut off in the vicinity of 7,000 or 8,000 cycles. The usual form of resistance coupled amplifier does this. Low frequencies also suffer when the generally recommended values of grid leak and coupling condensers are employed.

A theoretical discussion of resistance coupled audio amplifiers is not the pu

Fig. 3. Circuit of a television audio amplifier using a —27 first, and a pentode power stage.



pose of this article. However, it is well for the television experimenter to understand some of the fundamentals.

The high-frequency limit of an audio amplifier depends almost entirely upon circuit and tube capacities. The former can be reduced to a minimum by keeping the grid and plate leads short and as far away from other leads and metal objects as possible. Tube capacities are a different matter. We cannot alter the characteristics but we can select the type of tube having the lowest grid-filament and plate-filament capacities.

Tubes

The screen-grid tube, contrary to general opinion, is not the best tube for a television audio amplifier. To be sure, the gain is high but the inter-element capacities to ground are also high, particularly from plate to ground through the screen grid. The lumped sum of the tube and circuit capacities as well as the capacity of the coupling condensers in series with the plate resistors, tend to cut off the extremely high frequencies. The direct-coupled amplifier has proven one of the worst offenders since the cutoff starts at about 7,000 cycles. The ideal television audio amplifier would have a flat curve up to about 10,000 cycles with a gradual rise from 10,000 to 40,000, quite unlike broadcast amplifiers. Such an amplifier is not possible without special circuits making for complication and increased cost.

We can choose the "happy medium" by keeping the number of stages as low as possible using the type of tubes having the lowest grid-filament and plate-filament capacities. Then by selecting the proper size coupling resistors and condensers, we can construct a good amplifier.

With three-electrode tubes, the sum of the grid-cathode and plate-cathode capacities is somewhat lower than in the screen-grid types, but in order to obtain good amplification with reasonable plate voltages, the plate resistors should have a value between 20,000 and 25,000 ohms. As the coupling condensers are in series with the plate resistors (with respect to the a-c. circuits) the total shunt capacity is still too high. The meaning of this becomes apparent when it is considered that, in order to offer low reactance to frequencies as low as 15 cycles, the coupling condensers should have a value of at least 4 mfd., depending to a large extent upon the value of the grid resistors.

In television, the frequencies below 100 cycles can be of somewhat lower amplitude than the "highs" with very little effect upon the clearness of the picture, making it possible to employ a coupling condenser of relatively low

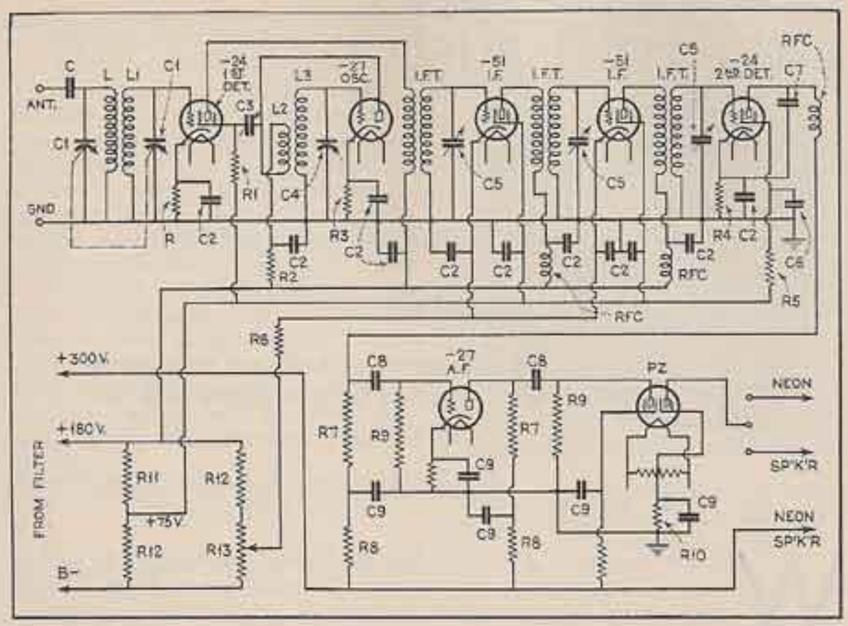


Fig. 4. Complete wiring layout using multi-mu tubes.

C	Antenna coupling condenser .000025 mfd.
C1	Two-gang tuning condenser .00015 mfd.
C2	.1 mfd. by-pass condensers.
C3	Oscillator coupling condenser .000025 mfd.
C4	Oscillator tuning condenser .00015 mfd.
C5	I-F. "peaking" condensers .00005 to .0001 mfd.
C6	Second detector screen-grid by-pass condenser 1 mfd.
C7	Second detector plate by-pass .00015 mfd.
C8	Audio coupling condensers .1 mfd.
C9	Audio by-pass and filter condensers 1 to 4 mfd.
L, L1	Short-wave band filter coils.
L2, L3	Oscillator coils.
IFT	Intermediate-frequency transformers.

RFC	Long-wave r-f. chokes.
R	First detector bias resistor 10,000 ohms.
R1	First detector screen-grid resistor 50,000 ohms.
R2	Oscillator voltage dropping resistor 25,000 ohms.
R3	Oscillator bias resistor 1500 ohms.
R4	2nd detector bias resistor 50,000 ohms.
R5	2nd detector screen-grid resistor 10,000 ohms.
R6	I-F. bias resistor 300 ohms.
R7	Plate resistors 100,000 ohms.
R8	Filter resistors 25,000 ohms.
R9	Grid resistors 250,000 ohms.
R10	Bias resistors 400 ohms.
R11	10,000 ohms.
R12	30,000 ohms.
R13	Volume control 10,000 ohms.

capacity, say .1 mfd. Then by using a rather high value of plate resistor, 100,000 ohms being a good value, and increasing the plate voltage to 300 or 400, we can obtain a fair degree of gain.

When a signal passes through a vacuum tube, it is shifted in phase 180 degrees, which means a complete reversal of the picture through each stage. Obviously, we must employ the correct number of stages to provide a "positive" picture. When the second detector is of the grid-leak type, one reversal takes place here and an odd number of a-f. stages would be necessary. With a bias type of second detector, an even number of a-f. stages would be required since rectification is in the plate circuit and no reversal takes place.

With a bias second detector two or four a-f. stages would be needed. Four would be rather difficult to place in operation due to feedbacks. We may employ only two stages using a '27 first and a pentode power stage. This combination would result in sufficient gain to operate any type of glow lamp. Fig. 3 shows the circuit of such an amplifier. R are the plate resistors of approximately 100,000 ohms each and R1 the grid resistors of 250,000 ohms. A-F. filters, resistors R3 and by-pass condensers C1, are connected in both detector and first a-f. plate voltage circuits to prevent motor-boating. The resistor R5 connected in the lead to the space charge grid of the power pentode will depend upon the value of B voltage available but will be within the limits of 10,000 to 20,000 ohms.

Fig. 4 shows the complete circuit of a television superheterodyne. A switch is provided in the output circuit of the power audio stage so that either a speaker or glow-lamp may be used at will.

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RADIO DIVIDENDS IN JULY

Dividends paid by radio companies in July amounted to $1,463,848, according to the Standard Statistics Company, of New York. Total cash dividend payments made by domestic corporations in July were $516,095,367.