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Factors Affecting the Fidelity of Radio Receiving Circuits

By the Engineering Department, Aerovox Corporation

IN common with all other parts of the radio receiver circuit the detector has been thoroughly revamped during the last year or two. For years the detector used a triode tube, nowadays it is nearly always a diode. The triode was used in two ways; that is, detection took place either in the grid-cathode circuit or in the plate-cathode circuit. In either case the actual process of detection took place in a two-element circuit, the third element taking little part in the detection process.

Thus the triode was really a diode detector and a three-element amplifier. The familiar grid leak and condenser detector detected in the grid circuit, using a non-linear part of the grid-current grid-voltage characteristic. Radio frequency signals put into this circuit encountered this non-linear characterstic and an average current was produced, just as in a vacuum tube voltmeter where a.c. voltages are converted into d.c. currents.

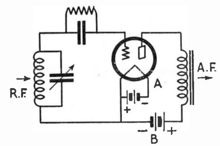

FIG. 1

This d.c. current flowing through the grid leak biased the grid accordingly. Audio frequency variations in the bias of the grid produced variations in the plate current of the tube and so the grid leak and condenser detector was really a detector plus an audio amplifier. For this reason the triode detector connected as shown in Fig. 1 was very sensitive. Since some current flowed in the input, or grid-cathode circuit, the detector drew power from the input tuned circuit. This loss of power resulted in a loss of selectivity because the input circuit of the tube was not of very high impedance and, shunted across the tuned circuit, lowered the Q or selectivity of that circuit. This was called "loading" the tuned circuit.

The other type of triode detector was the biased detector in which the grid was over-biased so that r.f. voltages put into the tube operated over a non-linear portion of the plate-voltage plate-current characteristic.

In this plate circuit detection took place and some direct current was produced as well as currents of audio frequency. These latter currents flowing through the plate load impedance produced a voltage there corresponding to the modulation of the carrier.

The triode in this connection may be thought of as an r.f. amplifier plus a plate circuit detector. Because the tube had a low impedance to radio frequencies it was not a very good amplifier at radio frequencies. Therefore, the triode in this connection, Fig. 2, was not so sensitive as the connection shown in Fig. 1. It has the advantage, however, of presenting to the tuned circuit input a very high impedance since the tube was so over-biased that little if any grid current flowed and therefore no power was taken from the input circuit. For this reason the tuned circuit in the detector input tuned very sharply.

Thus the grid leak, or grid circuit detector, detects and then amplifies; the plate circuit or biased detector amplifies and then detects. Ordinarily the first, and earlier form of detector, is several times as sensitive as the later form. This means simply that with a given input r.f. signal more audio frequency voltage would be produced and less audio amplification between the detector and the loud speaker was necessary.

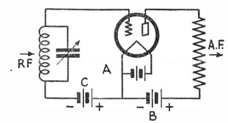

FIG. 2

In either case some direct current is produced; in the grid detector this d.c. appeared in the grid circuit and in the other case in the plate circuit. This direct current varies with the strength of the carrier input voltage and when the circuit is properly designed it is independent of the modulation of the carrier. This d.c. flowing through a fixed resistance produces a voltage drop which varies with the carrier, a strong signal producing a large voltage drop and a weak carrier producing a small voltage.

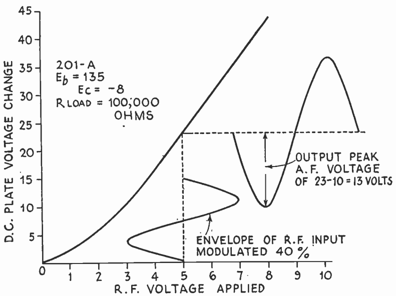

FIG. 3

These direct current voltages can be utilized as an automatic volume control by connecting the negative end of the resistor to the grid circuits of r.f. amplifiers in such a manner that on strong carriers the bias of these tubes is increased, lowering their amplification.

Distortion in Detectors

The trouble with the grid detector is its inability to handle very large input voltages. On strong signals the amount of d.c. was sufficient to overbias the tube which, acting as an amplifier, distorted badly. Furthermore, when this over-bias condition took place the tube began to detect in the plate circuit and so a combination of grid and plate detection took place. These detected products were out of phase and a fine mess of distortion often resulted. The grid detector was very sensitive to weak signals; but unless a very low value of leak resistance (a half-megohm, for example) was used this over-biasing action took place. The use of the low grid leak resistance produces excessive loading on the input circuit and broadened the tuning.

Therefore plate detectors came into vogue. The output characteristic of such a detector may be seen in Fig. 3. This detector would handle very large input signals, in fact on strong signals the ouput was freer from distortion than on weak signals because the characteristic becomes more nearly linear. The plate detector is a high impedance device; therefore it must be worked into a high impedance. It became good practice, then, to work this tune into a resistance load rather than a transformer which would have high impedance only to the higher audio frequencies. And so the voltage gain ordinarily secured in the transformer connecting detector to first audio tube was lost. There was no voltage step-up in the resistance-capacity network between detector and audio amplifier.

Linear Detectors

It was mentioned above that a more nearly linear detector produces less distortion. And yet detection will only take place in a non-linear circuit. How can these facts be reconciled? The characteristic of a truly linear detector is shown in Fig. 4. No such detector exists. The best of them have a curve at the bottom of the characteristic where the vertical line crosses the horizontal axis. But suppose a carrier signal is put on such a characteristic at the point where it crosses the axis.

Now all the negative half cycles will be cut off; all the positive half cycles will be reproduced accurately. In this process a change in plate current of the tube is produced, the average value will be somewhere between zero and the maximum of the positive half cycle. This average current will be an accurate reproduction of the modulation on the carrier. But if the characteristic has a curve in it as it crosses the axis, on weak signals the audio voltage will not be an accurate representation of the input carrier modulation. Distortion will exist. For this reason a linear detector is worked at a high level so that the bend in the characteristic near the axis is not used.

Such a characteristic can be obtained by using a two element tube; either by making use of a triode by connecting together as a single element the cathode and grid, or plate and cathode, or plate and grid. This was the first form of diode detection, Fig. 5. Subsequently tube manufacturers introduced true diodes, a cathode and a plate. The first tube of this type to come into general use was the 55 type of tube which had two diode plates and a triode in the same bulb and using the same cathode.

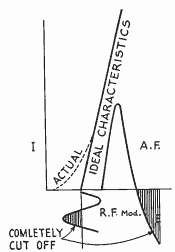

FIG. 4

In the diode detector there is no amplification. Furthermore this type of detector "loads" the input circuit; that is, it takes current and power from it. This means that the input circuit will not have as high impedance or be as selective as if a plate circuit detector is used. The advantage of such a detector lies in its linearity and hence its comparative freedom from distortion. Furthermore, in the detection process, there is a production of direct current proportional to the carrier voltage.

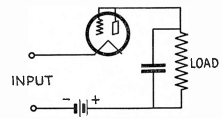

FIG. 5

This direct current in modern receivers, is caused to flow through a resistance and the voltage drop along this resistance is used to bias the grids of the radio frequency and intermediate frequency amplifiers, and sometimes the audio frequency amplifier and often the oscillator. All of this bias voltage variation is used to maintain the input voltage to the detector at a constant value—in other words the detector not only detects, separating the modulation from the carrier, but provides the automatic volume control voltage as well.

The circuit feeding power to the diode detector must be engineered carefully; usually this circuit operates at an intermediate frequency voltage built up to the desired value by considerable amplification both before and after the frequency is lowered from the carrier frequency entering the set via the antenna. The transformer connecting the detector to the preceeding tube must be closely coupled.

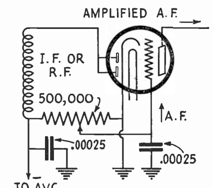

FIG. 6

The resistance across which the a.v.c. voltage is developed must be properly by-passed for i.f. currents. The relative impedances of this by-pass condenser and the resistor must be carefully considered. The condensers and resistors themselves must be of high quality. Values usually found in practice are shown in the typical diagram.

Precautions in the Use of Electrolytic Condensers

The electrolytic condenser has a unique characteristic which must always be kept in mind when using such condensers. This characteristic applies to the voltage at which the electrolytic condenser can be operated, as electrolytic condensers have a sharp defined voltage below which operation is perfectly safe, and above which voltage operation is definitely injurious.

This characteristic is due to the fact that the voltage for which the electrolytic condenser is designed to operate is determined by the film formed on the anode or positive film. This film has a very distinct voltage characteristic. Below the voltage at which it is formed it has relatively low d.c. leakage characteristics. More specifically, below the formation voltage the leakage on a direct voltage is sufficiently low as not to affect the performance of the condenser. However, above the voltage at which the film is formed the leakage rapidly increases and this excess leakage causes the condenser to heat up. Therefore, if operation at higher than rated voltage is continued for any considerable period of time, the heating becomes excessive and causes an increase in power factor and a drop in capacity. In the case of high voltage units the heating may be sufficient to finally cause the condenser to break down.

Because of these considerations it is essential that great care be exercised in the use of electrolytic condensers. Properly used they have long life and give satisfactory service. But, if continuously subjected to voltages in excess of their rating, failures are to be expected. Aerovox condensers are, of course, made to include a factor of safety to allow for unusual conditions, but this factor of safety is not for the purpose of permitting the condenser to be operated at voltages in excess of its rating.

Another factor of importance in this matter is the question of line voltage variations. In all cases it is desirable that the rated operating voltage of the condenser not be exceeded under conditions of maximum line voltage which may be impressed on the receiver.