Tuning Indicators and Circuits for Frequency-Modulation Receivers*

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Summary—**Frequency modulation provides good reception, but requires operation at resonance. The circuits described in these pages are applicable to standard receivers and provide effective means for accurate tuning. Some of these circuits include additional diodes, triodes, and combinations of diodes and triodes to produce sharp determination of the discriminator crossover point. A novel tuning eye employing two grids is suggested for a simplified tuning indicator.**

Tuning a Frequency-Modulation Receiver

THOSE who have had occasion to use a frequency-modulation receiver are aware of the necessity for a good visual tuning indicator. Here it is a case of "must," since reception exists for such an extended range around the correct tuning point. The results of mistuning are quite different in the case of frequency modulation. Here there is little change in audio-frequency characteristic and the volume level remains essentially constant as the receiver is tuned in and out of resonance.

At resonance, the noise is at a minimum and so also is the distortion. Slight mistuning may cause only a small increase in the ordinary type of background noise, but the high audio frequencies and all frequencies fully modulated will be noticeably distorted. The reason for this is that the frequency-modulation detector is a balanced circuit and depends upon exact resonance to deliver undistorted signals to the audio amplifier. This balance likewise results in the canceling out of amplitude changes, which are the unwanted responses, such as noise. Just how effectively the

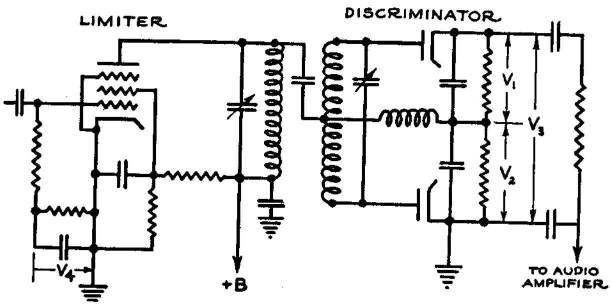

Fig. 1—Conventional frequency-modulation circuits.

frequency-modulation radio eliminates interference, then, depends to a very large extent upon this balance of the discriminator. With even slight mistuning, the ignition of a passing car will produce an annoying staccato that would not be audible with the receiver tuned to resonance.

It is logical to assume, then, that if we are going to take advantage of all the benefits which frequency modulation affords—extended frequency range, increased dynamic range, decreased distortion, and freedom from noise—we must tune the receiver to exact resonance and there must be some means provided for indicating this condition.

Simplified Type of Indicator

The first and simplest method is similar to that used with the amplitude-modulation receiver. The grid of

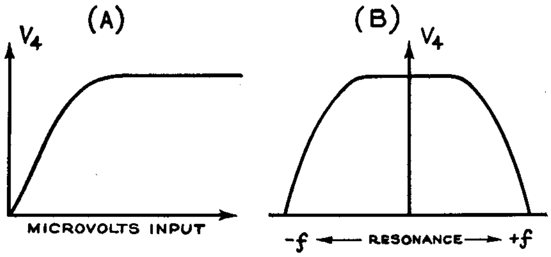

Fig. 2—Limiter rectified grid voltage.

the eye tube receives voltage V_4 from the limiter grid circuit (Fig. 1) and will, therefore, indicate the peak of the over-all selectivity curve. This is an indirect method of approach because the correct tuning point is the balance of the detector and this method assumes that the receiver is and remains perfectly aligned throughout, so that the selectivity curve is perfectly symmetrical and the discriminator curve is centered upon it.

In actual practice it has not only been found impossible to keep the over-all selectivity characteristic sufficiently symmetrical, but the curve shape will alter as the strength of the incoming signal changes. Moreover the selectivity curve is so broad that the eye is insensitive and on very strong signals a glance at the curve in Fig. 2 (B) will show how little aperture change can be expected for quite a departure from resonance.

However inadequate this method may seem, it is still better than no indicator at all and has been used with some degree of success on many receivers.

Circuits for Accurate Tuning

The direct method utilizes the voltages from the discriminator and of necessity involves greater complication. Exact resonance occurs when the incoming wave is centered on the detector curve so that, according to Fig. 3, V_3, the sum of voltages V_1 and V_2, is zero. These are direct voltages.

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By actually placing a voltmeter, preferably of the center-zero type, directly across the discriminator load, the receiver may be tuned accurately. However, the meter has been considered unsuitable and the next step is to find out how the tuning eye can be utilized. If its grid is connected to the high side of the discriminator load, voltage V_3 will cause the aperture to increase and decrease but there will be no way of determining where the zero-voltage point occurs. It is therefore necessary to establish some zero-voltage reference point. This may be done in several ways.

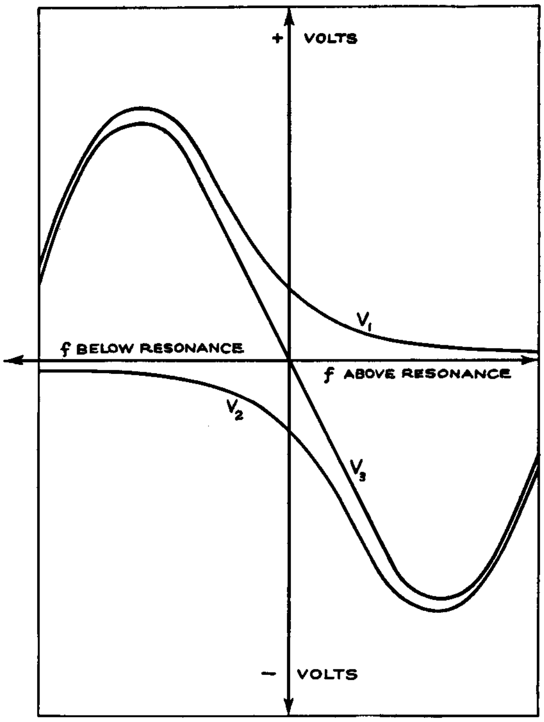

Fig. 3—Discriminator voltages.

The tuning indicator can be operated with an initial fixed bias sufficient to close the aperture when the voltage V_3 from the discriminator is zero. When V_3 becomes positive then, the eye will open and when V_3 swings negative, the eye will overlap. Thus the point of zero voltage or correct tuning is established. Some form of potentiometer must be provided with this method, since changes in line voltage, tube characteristics, etc., will require a readjustment of this reference point.

An alternative means of accomplishing this same function but avoiding the necessity of regularly checking the zero points consists in providing enough bias voltage to close the eye part way. A switch is then placed across the discriminator load so that when closed, the voltage on the eye grid is zero. By tuning the receiver until the tuning indicator aperture is the same for both positions of the switch, the correct point for true resonance is assured.

Since a manually operated switch is undesirable, it may be replaced by a contactor of special design such as shown in Fig. 4. This is a vibrating contact operating on alternating current to produce rapid intermittent short-circuiting of the tuning indicator grid to ground. The result is two eye apertures, one remaining fixed and representing the interval when the grid is grounded and the other opening and closing according to the voltage V_3. Correct tuning will occur at the point where these two apertures coincide.

A desirable variation here is shown by the dotted line, where the negative voltage for the initial bias is supplied by the limiter grid circuit. Because the bias from the limiter is zero when no station is being received, the tuning indicator is wide open, but narrows as a station is approached on the dial. This circuit change makes operation less confusing, since there is a difference then between the condition where no station is being received and the case of reception with the radio tuned exactly to resonance, both occurring when V_3 is zero.

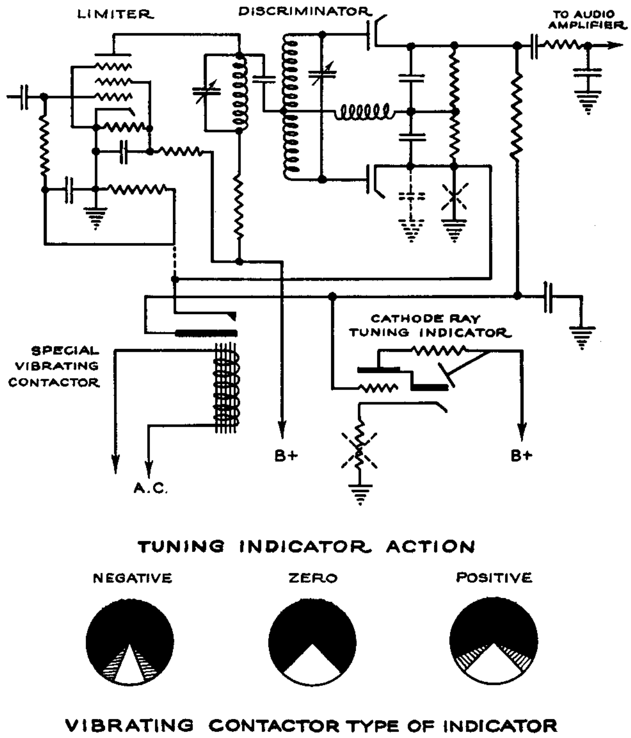

Fig. 4

Another method is to put the positive and negative discriminator voltages through special circuits so that they will each produce a voltage in the same direction. This is shown in Fig. 5 where a double diode and double triode are used in addition to the indicator tube.

Here the detector voltage is impressed upon the cathode of one diode and the plate of the other, the two other corresponding electrodes being grounded through resistors across which voltages are developed and impressed upon the triode grids. It is apparent that through the unidirective action of each diode, one triode will receive only negative voltage and the other only positive. The latter, therefore, will have its plate current increased with a consequent lowering of the plate voltage through an increased drop in the load resistor. This will decrease the voltage on the focusing

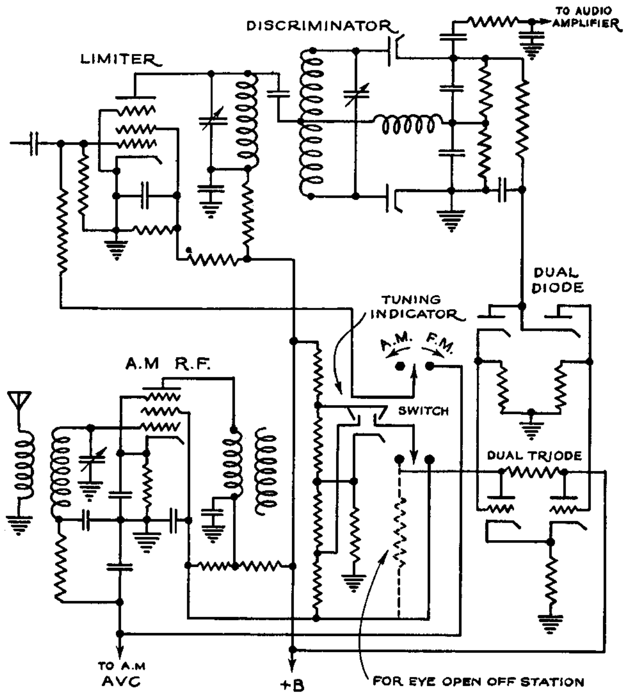

Fig. 5—Dual-diode and dual-triode indicator circuit.

electrode of the tuning indicator, since it is attached to this triode plate, and the eye aperture will increase. In a like manner, a negative voltage at the discriminator will tend to decrease the plate current of the second triode and thereby reduce the voltage drop in the cathode resistor, effectively decreasing the bias on the first triode to produce the same effect again. Therefore,

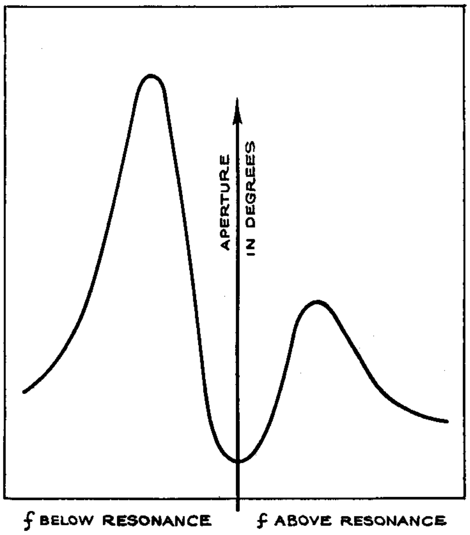

Fig. 6—Indicator aperture angle using circuit of Fig. 5.

on either side of resonance the eye will open and good reception can be assured in the regular manner by tuning for the greatest closing of the eye.

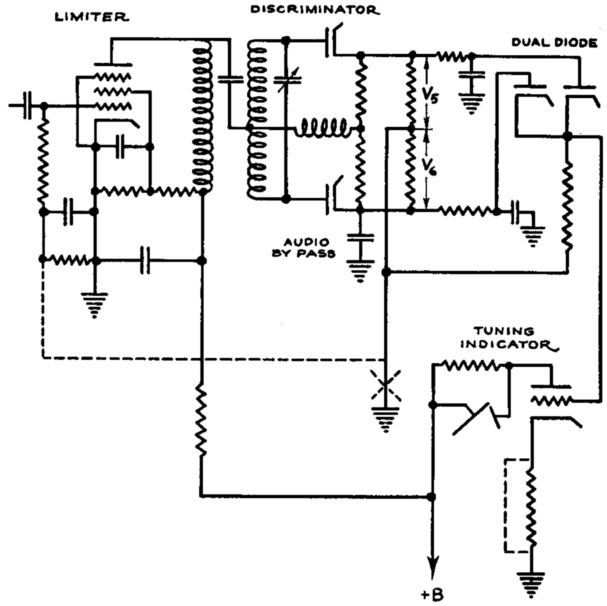

Fig. 7—Dual-diode indicator circuit.

By proper choice of resistors, the eye can be just closed for the condition of zero voltage across the detector. This is an extremely sensitive tuning device, more so than the voltmeter, and requires no preliminary setting up.

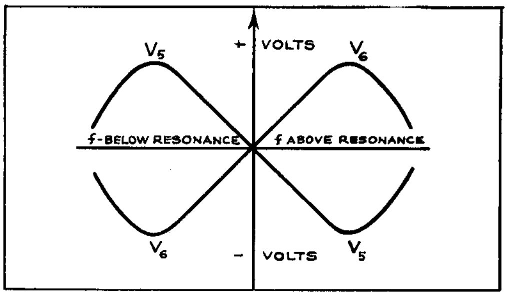

Fig. 8—Discriminator voltages.

The second portion of the eye is actuated by the biasing of an auxiliary tube with the negative voltage derived from the limiter grid circuit and may be omitted, of course.

Since the first section of the tuning indicator is closed when no signal is received as well as for the condition of exact resonance to a received signal, the operation may be confusing. However, this can be overcome by the addition of the resistor shown dotted in Fig. 5. This reduces the voltage of the electrode controlled by the discriminator when no station is being received. As a signal is approached the voltage on the electrode connected to the single triode rises because of the increase in bias voltage supplied from rectification in the limiter grid circuit. The voltage on the discriminator-controlled electrode will also rise because of the connecting resistor, so that when the station has been correctly tuned, the combination of effects will result in both apertures of the tuning indicator being closed.

A curve of the change in aperture angle with tuning

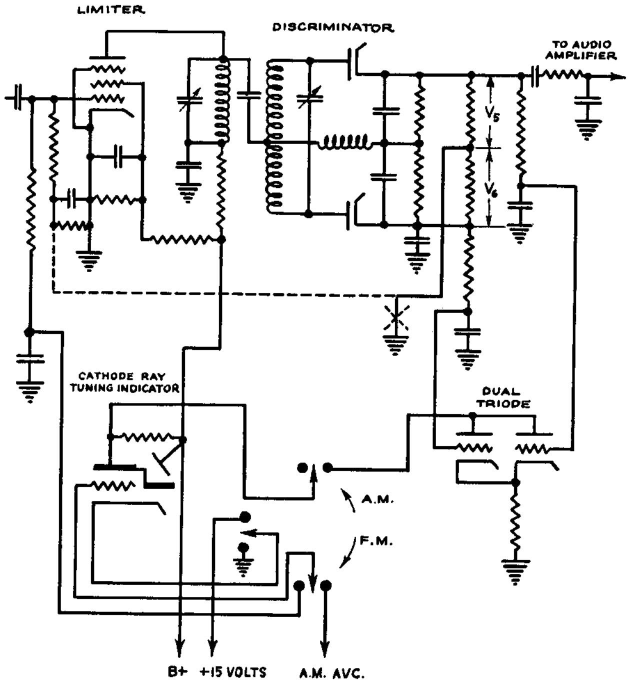

Fig. 9—Dual-triode indicator circuit.

is shown in Fig. 6 and it will be observed that the effect is more pronounced on the side for which the discriminator voltage is positive. This would be expected, since a direct effect is produced, while the negative voltage operates indirectly through the second triode. However, the lack of symmetry does not interfere

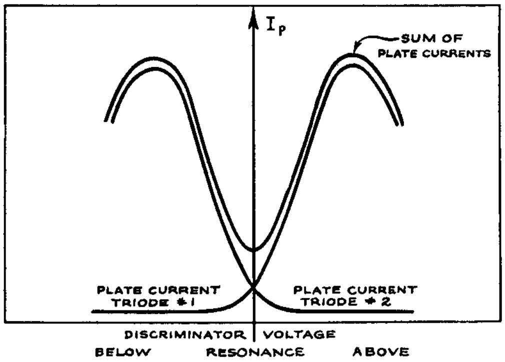

Fig. 10—Plate-current characteristics of dual-triode in Fig. 9.

with the effectiveness of the indicator, since it lies outside of the close-tuning area.

In Fig. 7 is shown a relatively simple yet useful circuit whereby the positive and negative detector voltages are both converted to positive voltages and then impressed on the eye-tube grid. It will be noticed that the direct-current ground has been removed from the cathode of the discriminator diode and has effectively been placed at the electrical center of the load so that the voltages with respect to ground are of the form shown in Fig. 8. A by-pass condenser is used to ground the low side of the discriminator load for audio frequencies, as it is still necessary to deliver the full amount of detected audio frequencies to the audio amplifier.

With this type of indicator it is necessary to use a sharp-cutoff eye tube so that sufficient sensitivity can

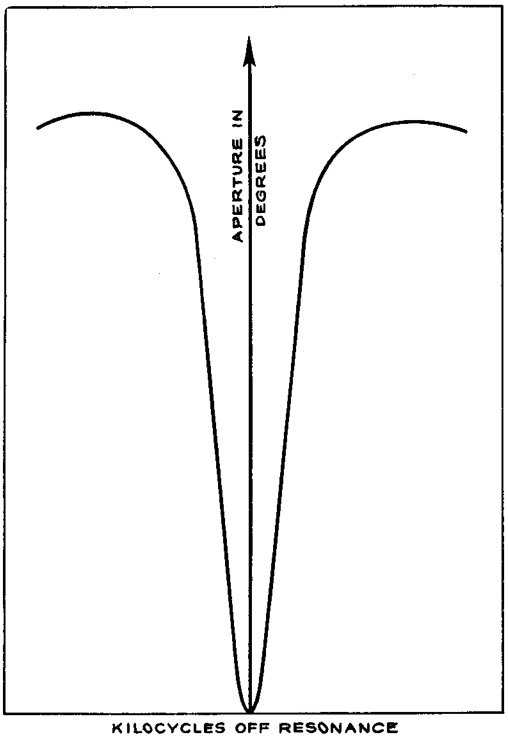

Fig. 11—Tuning indicator aperture angle with circuit of Fig. 9.

be obtained for accurate tuning. In combination amplitude-modulation and frequency-modulation receivers

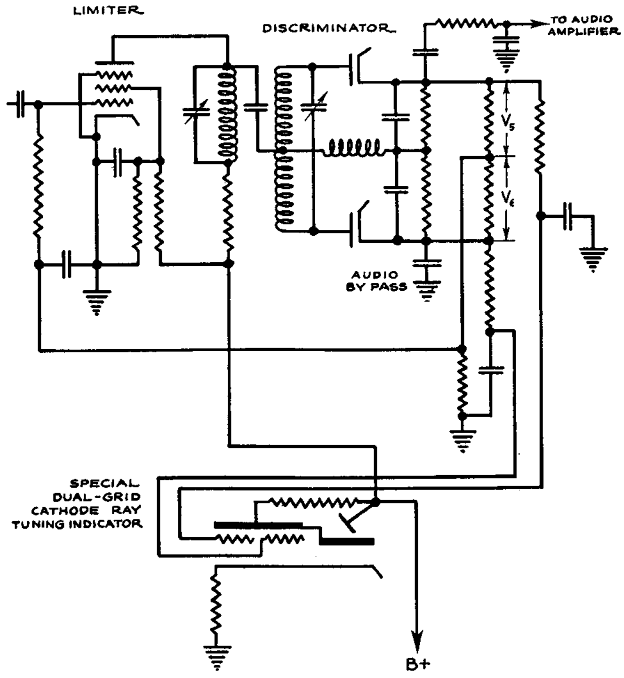

Fig. 12—Indicator circuit using special eye tube.

where the same indicator tube would logically be used, this imposes an undesirable restriction, since amplitude modulation requires an indicator tube of the remote-cutoff type.

Better results may be obtained with the use of the circuit shown in Fig. 9 where a dual sharp cut-off triode receives the voltages of Fig. 8. It can be seen from the curves that when one grid is positive, the other is negative by an equal amount and at first thought it would seem that any effect produced on the tuning indicator by one triode would immediately be canceled by the other. However, since these triodes are operated in the region of plate-current cutoff, the negative grid voltage from the discriminator produces a negligible plate-current change but the corresponding positive voltage on the other grid causes an abrupt plate-current rise. The two plate-current curves are shown in Fig. 10 and added to give the total current flowing in the load resistor. The plate voltage, which the focusing electrode receives, is of the same form and the over-all tuning characteristic appears in Fig. 11.

Not only is this type of indicator symmetrical, but also extremely sensitive. Here again by using a portion of the limiter grid voltage, the eye can be open when no station is being received and closed only when a signal is correctly tuned. This variation is shown dotted in Fig. 9.

If it is found desirable to use the more frequently found tuning indicator with the remote-cutoff triode in the same envelope, provision must be made for biasing this unwanted triode beyond plate-current cutoff, since it is connected internally to the focusing electrode and the slightest conduction will render the indicator circuit insensitive.

If an indicator tube of the sharp-cutoff type is used, however, the included triode will form one branch of the circuit and only a single additional triode will be required.

Special Indicator Tube

Proceeding a step farther by designing a special indicator tube for this service, the function can be performed with a minimum of equipment as shown in Fig. 12. Here a sharp-cutoff indicator tube with two identical grids is used in the same manner as the separate dual triode and eye tube in the circuit previously described. This functions very well for frequency modulation but is unsuited to the remote-cutoff requirements of amplitude modulation.

The possibility exists of making one of these indicator tubes with two sharp-cutoff grids and a third remote-cutoff grid to be used especially for combination amplitude-modulation—frequency-modulation receivers with a consequent saving in tubes but such an eye has yet to be designed.

Maintenance of Broadcast Operations in Wartime*

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Summary.—**This paper deals with the technical measures which have been taken in Canada by the Canadian Broadcasting Corporation to meet the daily increasing difficulties of maintenance of broadcast operations in war time. After a brief description of the facilities involved in these plans the paper outlines the steps that have been taken in the physical protection and guarding of broadcast plants. The problem of conservation of equipment in the face of acute shortages is then discussed with the measures that have been applied to prolong the life of tubes, microphones, and other equipment. In treating the final aspect of the problem, that is, the maintenance or resumption of essential operations after destruction of regular facilities, the paper describes the setting up of emergency and stand-by facilities such as secondary control centers, stand-by transmitters, frequency-modulation links, and other equipment designed to insure continuity of service.**

FOR THE Canadian Broadcasting Corporation, the problem of maintaining its operations in wartime is essentially the same as that which faces American broadcasters. It is confronted with the same serious economic difficulties, with the same dangers of sabotage, and finally with the same possibilities of enemy action which may bring about the destruction of its facilities.

Compared to the individual broadcasting station, however, there is one important difference, and that is, its much greater obligations as a publicly owned national service. The Canadian Broadcasting Corporation has been created as an independent, nonprofit-making institution responsible to the Canadian Government to provide a national broadcast service to all Canadians; this service, which is now even more vital than ever before, must be maintained whatever may be the difficulties which rise in its path. For this reason it may have gone more deeply into the problem than has the average station and has concerned itself, not only with measures of plant protection and equipment conservation, but also with measures designed to insure continuity of service in the event of destruction of some of its facilities.

With 10,000 miles of transmission lines operating through five time zones, the CBC network extends from Sydney, Nova Scotia, to Vancouver in British

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