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LB-887

REFLEXED INTERCARRIER SOUND

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RCA LABORATORIES DIVISION
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Approved

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Introduction

This bulletin describes a circuit for simplifying intercarrier sound receivers. This simplification is accomplished by employing the last i-f stage to amplify the 4.5-Mc intercarrier beat as well as the picture and sound i-f carriers. In receivers which use two pentode stages for sound i-f amplification, the basic cost reduction resulting from reflexing consists in the elimination of one of these tubes and its associated power drain. In receivers which use the video amplifier as an intercarrier sound amplifier, the substitution of reflexing through the video i-f amplifier produces higher gain with less amplitude modulation, particularly where the video amplifier is designed to provide effective noise clipping.

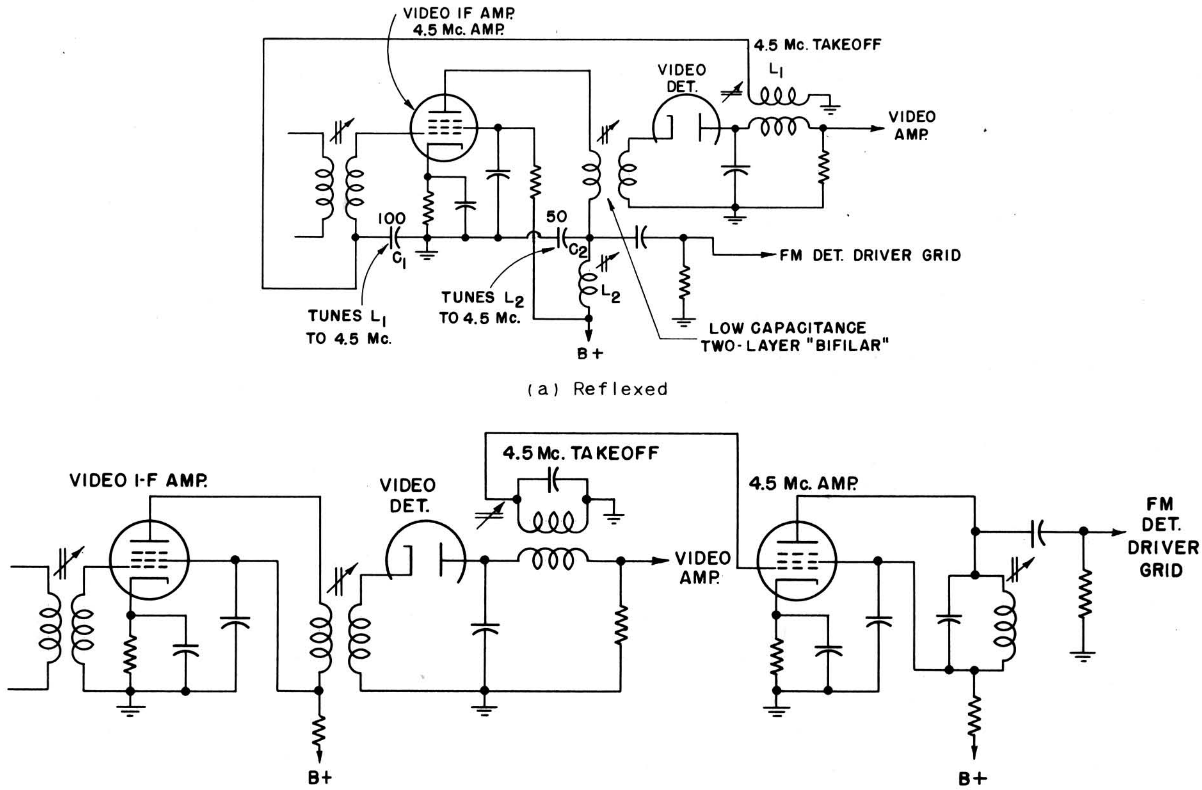
With good design no difficulty was experienced with crosstalk between the picture and sound signals, the stability and gain of the video i-f amplifier were unaffected, and stable gains at 4.5 Mc of the order of 40 db were obtained. No undesirable effects on either the picture or sound channel were noted under impulse noise conditions. Because of the greater frequency separation between the 4.5-Mc intercarrier beat and the intermediate frequency in 41-Mc i-f receivers, reflexing is more readily applied to 41-Mc receivers than to 21-Mc receivers.

Reflexed Circuit

The basic circuit applied to a 41-Mc i-f receiver is shown in Fig. 1a. This circuit may be compared with a commonly used circuit shown in Fig. 1b which employs an amplifier preceding the f-m detector driver. In the reflexed circuit, the 4.5-Mc voltage is taken off in the same manner and fed into the grid circuit of the last video i-f stage. This is accomplished by ungrounding the low side of the video i-f coil and using the tank condenser of the 4.5-Mc tuned circuit to complete the video i-f circuit.

A similar arrangement is used in the plate circuit of the video i-f amplifier. Here the cold side of the bifilar plate winding is opened and a 4.5-Mc tuned circuit is inserted. Again the tank condenser of this 4.5-Mc tuned circuit serves to complete the video i-f circuit of the last video i-f stage. The amplified 4.5-Mc signal developed across the tank circuit is fed to the grid circuit of the f-m detector driver. From this point, the reflexed circuit is the same as the unmodified circuit. A comparison of the two circuits shows that the saving which results from the reflexing consists of the elimination of the amplifier tube, the socket, several resistors and condensers, and the associated power drain.

Several versions of this circuit were considered. The one shown in Fig. 1a has the advantages of simplicity and effectiveness in isolating the video i-f and 4.5-Mc circuits.



(a) Reflexed

(b) Conventional

Fig. 1 - Reflexed and conventional intercarrier sound circuits.

Cross Modulation

To obtain optimum performance from the reflexed amplifier, it is necessary to minimize the possibility of cross modulation of the sound into the picture. This in turn requires that the 4.5-Mc level at the grid be kept to a low value. In order to obtain the greatest 4.5-Mc output consistent with this requirement, the 4.5-Mc load impedance in the plate of the reflexed tube should be as high as possible. This reduces the amplitude of the 4.5-Mc excursions of plate current for a given 4.5-Mc output. The impedance level in the grid circuit of the reflexed tube may then be made relatively low, which is desirable from the viewpoint of (a) making it possible to provide good video i-f bypassing, (b) reducing the level of the 4.5-Mc grid swing, and (c) making the circuit stable as far as grid-plate feedback is concerned.

In receiver designs where the video detector operates at a relatively low level, there is little possibility of cross modulation of the sound into the picture. However, satisfactory operation has been obtained even in receivers which have relatively poor a.g.c. and where the detector operating level rises to almost the full capability of the last video i-f stage. Under these conditions it is important to adequately bias the last video i-f tube. In the case of the type 6CB6, a bias resistor of not less than 180 ohms is required. The screen should preferably be fed through a series dropping resistor so as to provide an operating screen voltage of 150 volts, with degeneration of the d-c operating point by means of the series resistor.

Again from the viewpoint of minimum cross modulation of the sound into the picture, the video i-f gain of the reflexed tube should be as high as possible so that the tube is operated with minimum grid swing for a given output. In a stagger-tuned amplifier, the frequency of the last video i-f tuned circuit should therefore be close to the picture carrier frequency since

The maximum amount of energy in the signal is in the neighborhood of the picture carrier. It has been general practice to design receivers so as to meet this requirement.

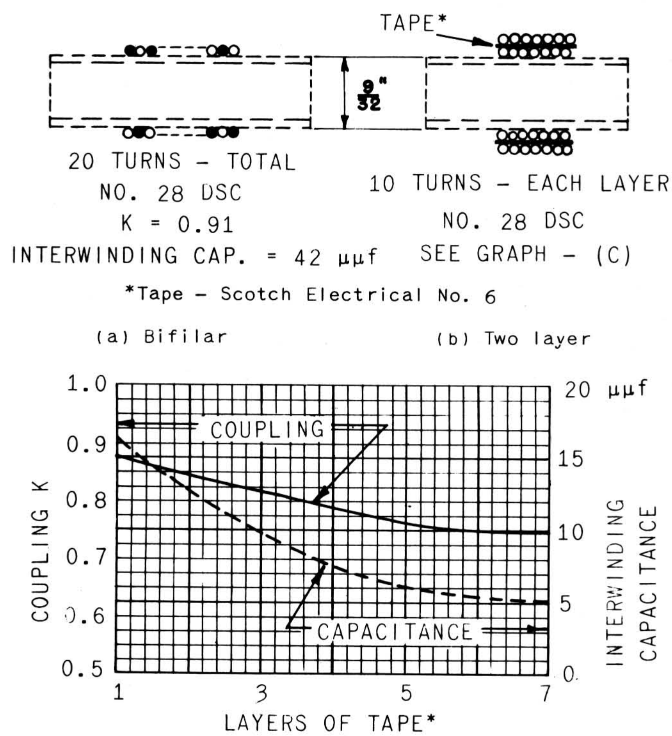
4.5-Mc Feedthrough

In this circuit the 4.5-Mc signal developed at the video detector is applied to the grid of the last video i-f tube. If enough of the amplified 4.5-Mc output should reach the video detector as a result of 4.5-Mc feedthrough to the secondary winding of the video i-f plate transformer, regeneration will result. Fortunately, the difference between the 4.5-Mc intercarrier beat and the video i-f frequency is sufficiently great so that regeneration can be prevented.

There are two paths by which the 4.5-Mc energy can reach the secondary winding. One is through capacitive coupling between the primary and secondary windings of the bifilar transformer, since the entire primary winding is "hot" at 4.5 Mc. The second source of 4.5-Mc voltage across the secondary winding is that due to inductive coupling between the two windings. Both of these sources of coupling are analyzed in the Appendix. For a typical 41-Mc bifilar winding with unity coupling, it turns out that 1 volt of 4.5-Mc signal at the grid of the reflexed tube will induce a voltage of 0.14 volt across the secondary. If it is further assumed that the grid-to-plate gain at 4.5 Mc is equal to 100, then the effect of the capacitive coupling can be determined. It is shown in the Appendix that 2 μμf of interwinding capacitance will cause the same amount of voltage across the secondary winding (0.14 volt) as is due to the inductive feedthrough. Since this capacitance is distributed uniformly along the length of the winding, and since one side of the secondary winding is grounded, the effective capacitive coupling lumped at the "high" end of the windings is approximately one-third the distributed capacitance. The interwinding capacitance is therefore equal to 6 μμf for equal contributions to the secondary voltage from the inductive and capacitive couplings. There is no advantage in reducing the capacitive coupling below this value, since the capacitive and inductive couplings produce voltages across the secondary which are in quadrature.

Regeneration can also take place as a result of feedthrough of 4.5 Mc to the 4.5-Mc takeoff coil by direct capacitive coupling from the 4.5-Mc plate coil (L_2 in Fig. 1a) to the components in the video detector output circuit. This coupling can readily be eliminated by proper layout.

Emphasis is placed in this bulletin on the problems which arise when a single-tuned video i-f interstage drives the video detector because this coupling is more widely used than double-tuned transformer coupling. When double-tuned coupling is used, there is no problem introduced by the reflexing since both the inductive and capacitive feedthrough of 4.5-Mc voltage to the secondary winding is very much lower than when a bifilar winding is used.



(c) Two-layer transformer

Fig. 2 - Comparison of bifilar and two-layer i-f transformers. The variation in coupling coefficient and interwinding capacitance with separation of windings is shown in (c).

The conventional interwound or true bifilar construction shown in Fig. 2a is not suitable for use with reflexing because it yields interwinding capacitances of the order of 40 μμf. Very much lower capacitance can be obtained by winding the secondary directly over the primary as shown in Fig. 2b. The capacitance which results from this construction depends on the thickness of the dielectric and the dielectric constant separating the two windings. Although the coefficient of coupling falls as the windings are separated, (Fig. 2c), it is still possible to obtain coupling coefficients of the order of 0.8 and at the same time reduce the interwinding capacitance to approximately 6 μμf. It is not desirable to drop the coupling coefficient much below 0.8 because of the resulting reduction in the video i-f gain. It can be shown that the bandwidth of the circuit is independent of the coupling coefficient and that the gain is equal to 1 + k so that a 10 per cent drop in coupling coefficient produces a 5 per cent drop in gain.

In 21-Mc video i-f amplifiers, the impedance of the windings to 4.5 Mc is four times as great. This means that the inductive feedthrough will be four times as great as in 41-Mc i-f amplifiers. The capacitive feedthrough will also be four times as great for a given interwinding capacitance. In receivers using 21-Mc i-f amplifiers, therefore, the interwinding capacitance must also be held to 6 μμf if the capacitive feedthrough is not to exceed the inductive feedthrough. When this condition obtains, the feedthrough will be four times as great as in 41-Mc receivers. The greater amount of feedthrough at 21 Mc is to be expected since at 21 Mc the ratio between the video i.f. and the 4.5-Mc intercarrier beat is only 5 to 1 as against 10 to 1 for the 41-Mc frequency. There is also a possibility of the fifth harmonic of 4.5 Mc causing a beat with the picture carrier in 21-Mc receivers.

4.5-Mc Stability

The relatively high grid-to-plate capacitance of the type 6CB6 makes it worth calculating the maximum 4.5-Mc impedance in the grid circuit of the reflexed tube. Assuming that the grid-to-plate amplification is 100, the negative resistance contributed by the grid-to-plate capacitance is given by:

$$R = \frac{1}{\pi f C_{gp} g_m R_1} = \frac{1}{\pi \times 4.5\times10^6 \times 0.015\times10^{-12}\times 100}$$

$$= 47{,}000 \text{ ohms}$$

Thus the threshold of 4.5-Mc oscillation will be reached when the grid impedance at 4.5 Mc is equal to 47,000 ohms. To provide a reasonable safety factor, the grid impedance should not exceed some 20 per cent of this value or 10,000 ohms. If the grid circuit is tuned with 100 μμf, this implies that the operating Q of the 4.5-Mc grid-tuned circuit should not exceed 25 to meet this criterion of stability at 4.5 Mc.

Single-Tuned vs Double-Tuned Interstage

In arriving at the circuit in Fig. 1, consideration was given to the relative merits of the single-tuned vs double-tuned 4.5-Mc input to the f-m detector-driver tube. It was decided to use single-tuned interstage coupling on the basis that no appreciable gain improvement could be obtained with a double-tuned transformer. If a double-tuned transformer is used, its primary must be tuned with at least 60 μμf in order to provide an adequate video i-f bypass. Its secondary must tune with essentially the same amount in order to avoid excessive detuning with changes in signal level and to avoid excessive reduction in secondary circuit Q due to grid loading. Since the double-tuned circuit thus requires a total capacitance of almost 100 μμf, it offers no gain advantage over the single-tuned circuit. However, it may be used where the additional adjacent channel selectivity is desired.

4.5-Mc Rectification

In the course of work on the reflexed circuit it was noted that the nonlinearity in the last video i-f stage produces a 4.5-Mc component which feeds directly into the f-m detector driver grid circuit, bypassing completely the normal 4.5-Mc takeoff circuit. The amount of 4.5-Mc signal produced in this way was found to be approximately 20 db down and did not produce any undesirable effects.

Layout

Radiation of the second and fourth harmonics of the video i.f. from the vicinity of

The last video i-f stage and the video detector is always a problem. Where reflexed intercarrier sound is used, the layout should be such as to minimize chassis currents and lead lengths. To obtain short bypass leads at 41 Mc and its harmonics, the grid and plate tank condensers of the 4.5-Mc circuit should be placed directly at the video i-f tube socket. The plate 4.5-Mc coil may be placed close to the plate video i-f transformer to avoid 4.5-Mc chassis currents.

Jack Avins

Appendix

Calculation of Feedthrough

The following conditions are assumed:

(a) I-f load circuit resonant at 45 Mc with total of 15-μμf capacitance.

(b) 1-volt 4.5-Mc signal at grid of reflexed video i-f tube; g_m = 6000 μmhos.

Since X_L = 24 ohms at 4.5-Mc, the 4.5-Mc signal induced across the primary is equal to

$$e_{ind} = 6000 \times 10^{-6} \times 24 = 0.14 \text{ volt.}$$

If the coupling is unity, the voltage across the secondary will equal 0.14 volt.

The capacitive component of 4.5-Mc voltage across the secondary is readily calculated. If the grid-plate amplification is assumed as 100, and the capacitive reactance of the interwinding capacitance is equal to X_C, then the voltage across the secondary = $100 \times \frac{24}{X_c}$ volts. If this is to equal the inductive component

$$100 \times \frac{24}{X_c} = 0.14$$

$$X_C = 17{,}000 \text{ ohms}$$

and $$C = 2 \ \mu\mu f$$