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I.F. AMPLIFIER WITH ELECTRONICALLY CONTROLLABLE BAND-PASS

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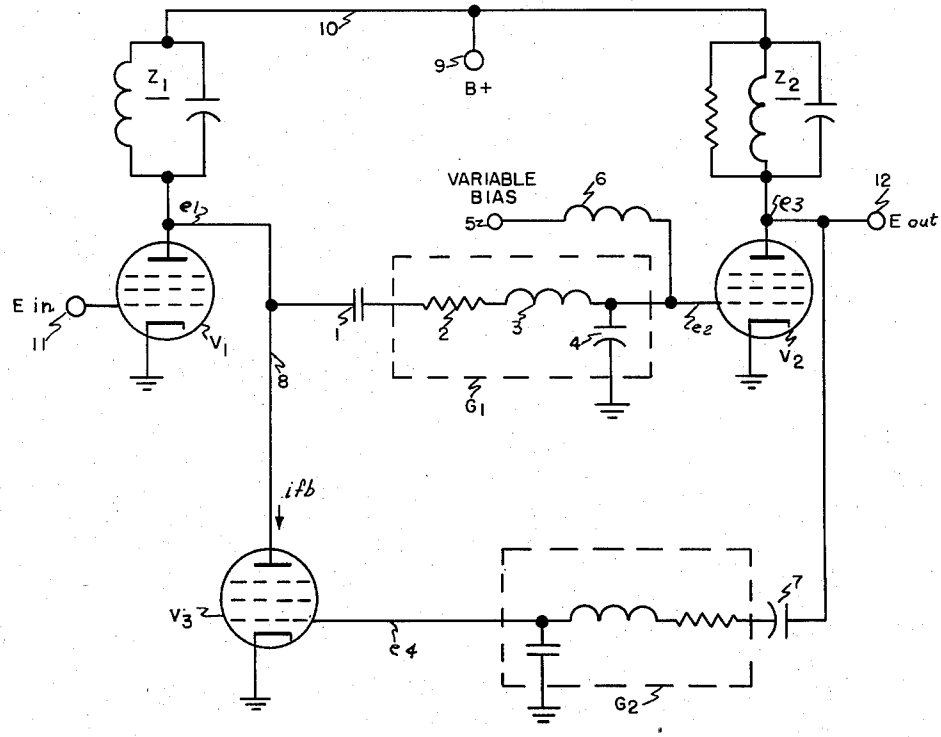


FIG. 1

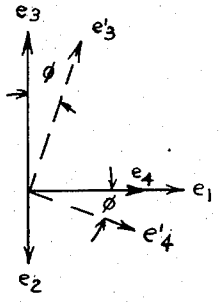


FIG. 2

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I.F. AMPLIFIER WITH ELECTRONICALLY CONTROLLABLE BAND-PASS

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5 Claims. (Cl. 330—85)

This invention relates to an I.F. amplifier incorporating an electronically controllable band-pass filter.

It is an advantage in many applications to be able to control, at will, the band-pass of an I.F. amplifier. There have existed in the past coupling devices of the magnetic type in which a mechanical linkage was utilized to vary the band-pass characteristics of the coupling by physically altering the relative positions of two coupled inductances.

Such an arrangement is bulky and uneconomical, and during the variation of the coupling from a cascaded single tuned to a double tuned configuration the gain of the amplifier will be varied over a considerable range.

It is an object of the invention to provide an I.F. amplifier incorporating coupling means, the band-pass characteristics of which can be varied solely by electronic means.

It is a further object of the invention to provide such an arrangement in which the gain of the amplifier will undergo substantially no variation over the complete range of band-pass variation. It is another object of the invention to provide such an arrangement in which the bandwidth may be varied symmetrically about the center frequency merely by varying the bias of a single tube.

These and other objects and advantages of the invention can be realized in a cascaded arrangement of three tubes coupled by 90° phase shifting networks. The first two of these tubes are provided with parallel resonant circuits acting as load impedances and the three tubes are coupled by circuits which provide a 90° phase shift at the frequency to which the load impedances are tuned. The anodes of the first and third tubes are directly connected and the output of the circuit is taken across the load impedance of the second tube.

In the drawing:

Fig. 1 is a schematic diagram of an I.F. amplifier embodying the invention; and,

Fig. 2 is a vector diagram showing the phase relationships existing between the voltages at various points in the circuit of Fig. 1.

Referring more particularly to the drawing, there is shown in Fig. 1 an I.F. amplifier comprising three pentode tubes V_1, V_2 and V_3. The anode of V_1 is connected to a parallel resonant circuit Z_1 constituting the load impedance therefor. The tube V_2 is provided with a similar circuit Z_2 which, however, may be of lower Q than Z_1, as indicated by the presence of a resistor.

The anode of V_1 is coupled to the control grid of V_2 by way of a capacitor **1** and a phase shifting circuit indicated by the dashed box G_1 which comprises a series arrangement of a resistor **2** and a coil **3** shunted by a capacitor **4** to ground. The terminal **5** connects a source of variable bias voltage which is not shown to the control grid of V_2 by way of a choke coil **6**. While the circuit G_1 is shown as supplying a negative phase shift, one imparting a positive shift could be used as well.

The anode of V_2 is coupled to the control grid of V_3 by way of a capacitor **7** and a phase shifting circuit indicated by the dashed box G_2 which is identical with the

circuit G_1. The anodes of V_3 and V_1 are directly connected by way of a conductor **8**. Plate supply voltage is provided from a terminal **9** by way of a conductor **10**. Input to the circuit is from the terminal **11** to the control grid of V_1 and the output is taken at a terminal **12** connected to the anode of V_2.

The operation of the above described circuit can be understood by reference to the vector diagram of Fig. 2 which shows the phase relationships of voltages existing at various points in the circuit. The solid line vectors of this diagram relate to the on-frequency condition of the circuit, while the dashed vectors indicate the relationships existing when the signal is above the frequency to which the circuits Z_1 and Z_2 are tuned. Referring to the diagram and using e_1 as a reference we find e_2 lagging e_1 by 90° and attenuated with respect thereto by the action of the circuit G_1. The voltage at the plate of V_2 which is e_3 is then 180° out of phase with e_2 or at +90°. The effect of the second phase shifter G_2 is to cause e_4 to lag e_3 by 90° to put e_4 in phase with voltage e_1. The current i_{fb}, which is indicated as existing in conductor **8**, is caused to flow in phase with the voltage e_4 on the grid of tube V_3 and constitutes a dynamic pure resistive loading across the tank circuit Z_1.

Now let us assume that the frequency of the input is raised above the natural resonance frequency of circuits Z_1 and Z_2. At this frequency the tank circuit Z_2 will be capacitive. Therefore, the voltage e_3 now lags its former position by the angle ϕ as indicated by the vector e'_3. This will cause a corresponding lag of e_4 behind its former position as indicated by the vector e'_4. The effect of the resulting lagging current i_{fb} is as if in addition to a dynamic resistance a dynamic inductance had been connected across tank circuit Z_1. Inasmuch as circuit Z_1 is now also capacitive at the higher frequency, the sign of the inductive susceptance is correct to retune the circuit Z_1 to the new higher frequency. This is exactly the same effect that takes place between two inductively connected coils with a similar change in frequency. However, in the circuit illustrated the current i_{fb} is controllable in amplitude by varying the gain within the feedback loop, i.e., by varying the transconductance of tube V_2 by means of the bias voltage applied from the terminal **5**. It can be shown mathematically that such a variation of gain within the feedback loop is exactly analogous to mechanically varying the coefficient of coupling between two tuned circuits. By thus varying the bias voltage applied to tube V_2 constant gain with varying bandwidth over a wide range can be achieved.

The Q of the coil in the circuit Z_1 determines the minimum bandwidth which can be attained. If wide excursions of bandwidth are desired it is necessary to make the Q of this component as high as possible. The Q of Z_1 may be preserved if necessary by isolating it from the phase shift network with a cathode follower. The Q of the tank circuit Z_2 is maintained at a lower value to allow the band-pass of the front end of the circuit to be unmodified thereby over the desired range of frequency excursions.

The invention is available for several uses. One obvious use is in a radar set having a choice of two or more pulsewidths, each with its optimum bandwidth. Another use is as a replacement for mechanical devices used in certain communication receivers to vary the I.F. bandwidth. It can also be used in a search receiver which must search a given band as rapidly as possible, find the desired signal, and thereafter be relatively immune to nearby distracting signals.

While the disclosure has been limited to an arrangement in which bias is applied only to the second stage, it should be understood that other biasing arrangements may be used if other gain-bandwith configurations are

desired. For example, the bias may be applied to the third stage rather than the second. This will still provide control of bandwidth but gain will rise as bandwidth is decreased. Or bias may be applied to both the second and third stages. The resulting selectivity curve will be substantially the same as that of two inductively coupled circuits. With such a curve a substantially flat pass band can be achieved by following the illustrated circuit with a single tuned circuit, as pointed out for the inductively coupled circuit in the textbook, "Radio Receiver Design," by Sturley, published in 1947 by John Wiley & Sons, Inc., New York, N.Y., pp. 307–320 inclusive.

What is claimed is:

1. An amplifier comprising three phase inverting stages, means for coupling signals to the input of said first stage, a first parallel resonant circuit connected to form a load impedance for the first of said stages, means including a phase shifting circuit coupling the output of the first stage to the input of the second, a second parallel resonant circuit connected to form a load impedance for said second stage, means for obtaining output signals from said second stage, a phase shifting circuit coupling the output of said second stage to the input of the third of said stages, means for varying the gain of said second stage, and means applying the output of said third stage across said first parallel resonant circuit, said parallel resonant circuits being tuned to the same frequency and each of said phase shifting circuits being selected to shift the phase of energy applied thereto by substantially ninety degrees in the same sense at the said frequency to which said resonant circuits are tuned.

2. An amplifier comprising three phase inverting stages, means for coupling signals to the input of said first stage, a first parallel resonant circuit connected to form a load impedance for the first of said stages, means including a phase shifting circuit coupling the output of the first stage to the input of the second, a second parallel resonant circuit connected to form a load impedance for said second stage, means for obtaining output signals from said second stage, a phase shifting circuit coupling the output of said second stage to the input of the third of said stages, means applying a variable gain control bias voltage to said second stage, and means applying the output of said third stage across said first parallel resonant circuit, said parallel resonant circuits being tuned to the same frequency and each of said phase shifting circuits being selected to shift the phase of energy applied thereto by substantially ninety degrees in the same sense at the said frequency to which said resonant circuits are tuned.

3. An amplifier comprising three phase inverting stages at least one of which is a variable transconductance stage, means for coupling signals to the input of said first stage, a first parallel resonant circuit connected to form a load impedance for the first of said stages, means including a phase shifting circuit coupling the output of the first stage to the input of the second, a second parallel resonant circuit having a lower Q than that of said first parallel resonant circuit connected to form a load impedance for said second stage, means for obtaining output signals from said second stage, a phase shifting circuit coupling the output of said second stage to the input of the third of said stages, means for variably biasing said variable transconductance stage, and means applying the output of said third stage across said first parallel resonant circuit, said parallel resonant circuits being tuned to the same frequency and each of said phase shifting circuits being selected to shift the phase of energy applied thereto by substantially ninety degrees in the same sense at the said frequency to which said resonant circuits are tuned.

4. An amplifier comprising three phase inverting stage, means for coupling signals to the input of said first stage, a first parallel resonant circuit connected to form a load impedance for the first of said stages, means including a phase shifting circuit coupling the output of the first stage to the input of the second, a second parallel resonant circuit having a lower Q than that of said first parallel resonant circuit connected to form a load impedance for said second stage, means for obtaining output signals from said second stage, a phase shifting circuit coupling the output of said second stage to the input of the third of said stages, means applying the output of said third stage across said first parallel resonant circuit thereby completing a feedback loop including said three stages, and means varying the gain of said feedback loop, said parallel resonant circuits being tuned to the same frequency and each of said phase shifting circuits being selected to shift the phase of energy applied thereto by substantially ninety degrees in the same sense at the said frequency to which said resonant circuits are tuned.

5. An amplifier comprising three phase inverting stages, means for coupling signals to the input of said first stage, a first parallel resonant circuit connected to form a load impedance for the first of said stages, means including a phase shifting circuit coupling the output of the first stage to the input of the second, a second parallel resonant circuit connected to form a load impedance for said second stage, means for obtaining output signals from said second stage, a phase shifting circuit coupling the output of said second stage to the input of the third of said stages, means applying the output of said third stage across said first parallel resonant circuit thereby completing a feedback loop including said three stages, and means varying the gain of said feedback loop, said parallel resonant circuits being tuned to the same frequency and each of said phase shifting circuits being selected to shift the phase of energy applied thereto by substantially ninety degrees in the same sense at the said frequency to which said resonant circuits are tuned.

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