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PASS BAND WIDTH CONTROL CIRCUIT

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Fig. 1.

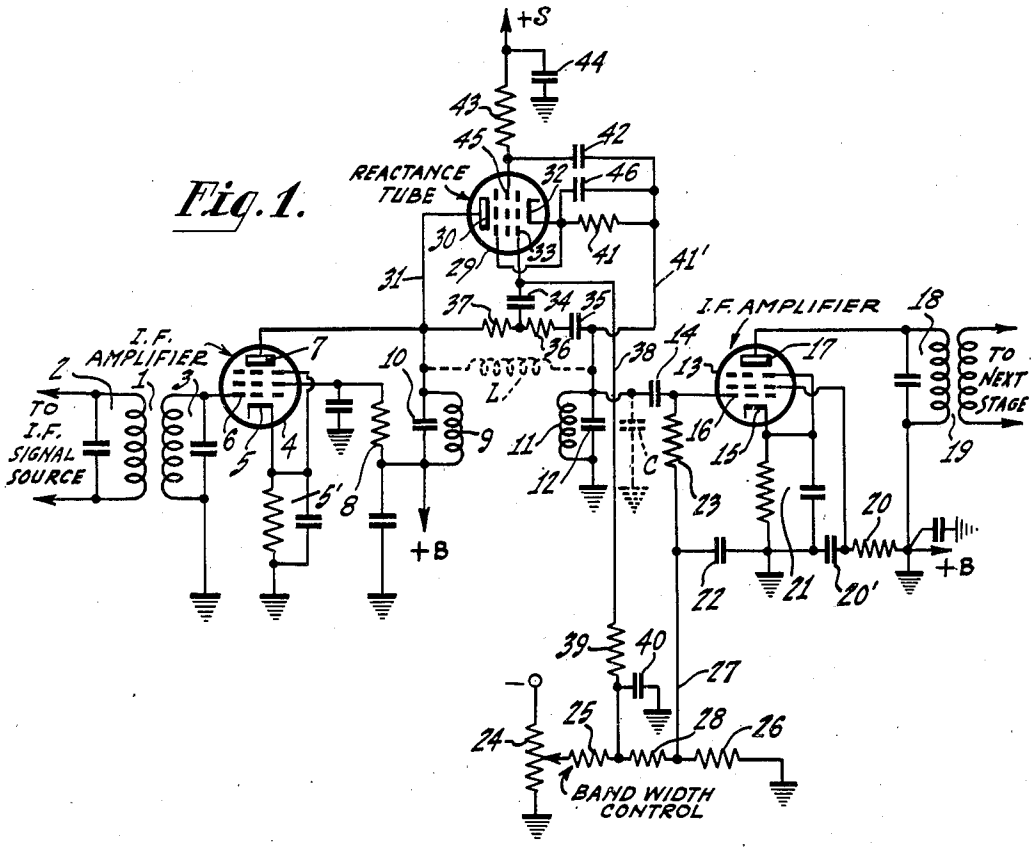
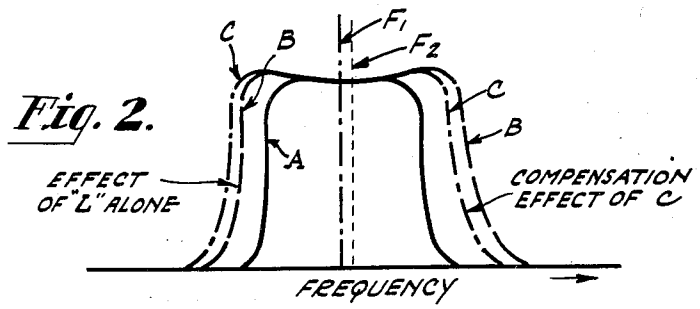


Fig. 2.



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PASS BAND WIDTH CONTROL CIRCUIT

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5 Claims. (Cl. 178—44)

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Our present invention relates generally to amplifiers of radio frequency waves equipped with means for adjusting pass band width, and more specifically to an electronic control circuit for selectively changing the width of the pass band of a modulated carrier wave transmission network.

One of the important objects of our present invention is to provide an electronic device for changing selectively the pass band width of a signal wave amplifier circuit, while concurrently maintaining the frequency response characteristic substantially flat and of a substantially constant mid-band frequency.

Another important object of our invention is to provide a method of coupling a pair of resonant radio frequency circuits by means of the plate to cathode impedance of an electron discharge device embodied in a circuit which causes the impedance to simulate an inductance having sufficient resistive component to provide a pass band response characteristic of substantially flat top.

Another important object of our invention is to utilize an electronic device as the sole coupling means between a pair of cascaded signal amplifiers, and to employ a single means for varying the coupling effect of the electronic device while varying the input capacitance of the second signal amplifier in such manner that the pass band width of the coupled amplifiers may be adjusted with substantially no effect on the mid-band frequency of the pass band.

A more specific object of our invention is to utilize a reactance tube for simulating inductive coupling between the cascaded resonant circuits of an I. F. (intermediate frequency) amplifier, a band width adjusting potentiometer being used for varying the gain of the reactance tube thereby to control the pass band width of the I. F. amplifier, and said potentiometer simultaneously changing the grid circuit capacitance of an amplifier tube in a sense to compensate for a change in mid-band frequency of the variably coupled circuits.

Still other objects of our invention are to improve generally the efficiency and simplicity of radio receivers of the type employing selectivity, or pass band width, control, and more especially to provide an adjustable pass band control circuit which is capable of being manufactured and assembled in an economical manner.

Other features of our invention will best be understood by reference to the following description taken in connection with the drawing in which we have shown diagrammatically a circuit organization whereby our invention may be carried into effect.

In the drawing:

Fig. 1 illustrates an embodiment of the invention as applied to a radio receiver of the superheterodyne type; and

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Fig. 2 shows ideal frequency response curves explanatory of the invention.

Referring to Fig. 1, which shows only so much of a radio receiver system as is essential to an understanding of our invention, the numeral 1 designates a suitable I. F. transformer whose primary circuit 2 may be located in the plate circuit of a prior I. F. amplifier tube or converter tube. The secondary circuit 3 is coupled to the input electrodes, grid 6 and cathode 5, of a following I. F. amplifier tube 4. It should be understood that our invention may, if desired, be employed in the radio frequency stage of a superheterodyne receiver or other radio apparatus. The receiver may be one adapted to receive amplitude modulated carrier waves, say in the 550 to 1700 kc. (kilocycle) broadcast range. In such case the selector circuits in each stage of the receiver may have a maximum pass band width such as to pass a 10 kc. band of modulation components. For example, the selector circuits, such as the circuits of transformer 1; the coupling circuits 9, 10, L, 11, 12 which supply the output of tube 4 to an additional amplifying stage; and the circuit of a succeeding stage coupling transformer 19 would each have a maximum band width of 20 kc. If the receiver were designed to receive frequency modulated carrier waves, the selector circuits would be designed, with present standards of FM broadcast transmission, to pass a band more than 150 kc. wide. In other words, our invention is independent of the nature of the modulation on the carrier waves, is independent of the transmission frequency range, and is also independent of the specific pass band width range of the selector circuits.

For the purpose of illustration, let it be assumed that each of cascaded selector circuits 2, 3, 9—10, 11—12, and 18 is tuned to an operating I. F. value of 455 kc., and that the system receives amplitude modulated waves in the broadcast band of 550 to 1700 kc. The transformer 19 may have its secondary coil feed any demodulator of suitable design for producing audio frequency signals for audio frequency amplification and reproduction. Interposed between cascaded I. F. amplifier tubes 4 and 13 are the coupled cascaded resonant circuits whose frequency response, or selectivity curve, is to be regulated in accordance with our invention.

The resonant circuits 9—10 and 11—12 are inductively coupled by a simulated element L indicated in dotted line. The coupling is across the high alternating potential sides of the resonant circuits. The inductive elements 9, L and 11 form a so-called "pi" coupling section in which the coupling means L provides the sole coupling between the input and output resonant circuits.

In the form of the invention shown in Fig. 1, the coupling inductance is provided by an elec-

tron discharge tube 29, shown as a pentode by way of example, having an electron-emitting cathode 32, electron passage control grid 33, screen grid 45, a suppressor grid, and electron-collecting plate 30. The plate 30 is connected by lead 31 to the plate 7 of amplifier tube 4 so that the plate or electron-discharge circuits of both tubes are in parallel.

Cathode 32 of reactance tube 29 is connected to ground over a path including bias resistor 41, lead 41' and coil 11. Hence, the plate to cathode impedance of tube 29 is effectively bridged across the high potential sides of the resonant circuits 10, 9 and 11, 12. The parallel resonant circuit composed of condenser 10 and primary winding 9 has the high alternating potential side thereof connected to the plates 7 and 30 of tubes 4 and 29 respectively. The low potential side of circuit 10, 9 is bypassed to ground for I. F. currents, and is connected to the +B terminal of a suitable direct current source, about +250 volts above ground for instance. The control grid 6 of amplifier tube 4 is connected to the high signal potential side of input circuit 3, while the cathode 5 is returned to the grounded side of input circuit 3 through the resistor of a suitable grid biasing network 5'. The screen grid of amplifier tube 4 may be connected to the +B plate supply terminal through a suitable voltage-reducing resistor 8, the latter being effectively bypassed for I. F. currents at both ends thereof.

The following I. F. amplifier is generally constructed in the same manner as the prior I. F. amplifier circuit. Tube 13 has its cathode 15 returned to ground through the resistor of a suitable grid bias network 21, while the plate 17 of the tube 13 is connected to the +B voltage supply terminal through the primary winding of I. F. transformer 19. The control grid 16 is connected through the direct current blocking condenser 14 to the high signal potential side of the resonant secondary circuit 11, 12.

The control grid 16 is returned to ground for direct current purposes through a path consisting of resistor 23 and resistor 26, the lower end of resistor 23 being bypassed to ground for I. F. currents through condenser 22. The screen grid of amplifier tube 13 may be connected to the +B terminal of the tube plate supply circuit through a voltage-reducing resistor 20 whose upper and lower ends are bypassed to ground for I. F. currents. It is to be clearly understood that tubes 4, 13 and 29 may be of any desired type suitable for the functions of the present invention. They are shown as tubes of the pentode type merely by way of illustration.

Returning now to the reactance tube 29 and its associated electrical circuits, the control grid 33 of tube 29 is connected to a suitable point on a phase shifter network through a direct current blocking condenser 34. The phase shifter network consists of resistors 37 and 36 and condenser 35 arranged in a series path across the simulated inductance L. The condenser 34 is connected to the junction of resistors 37 and 36, and the constants of the phase shifter network 37, 36 and 35 are so chosen that the alternating voltage across the series combination of resistor 36 and condenser 35, i. e. the input voltage applied to tube 29, has a phase angle of less than 90° with respect to the voltage between plate 30 and cathode 32 of tube 29. Since this phase angle is less than 90° a resistive component is added to the effective inductance L which has the effect of loading circuits 10, 9, L, 11, 12. Increasing the resistance of resistor 36 increases the resistive component of coupling element L, thereby increasing the loading across the bandpass network 10, 9, L, 11, 12.

Those skilled in the art of radio communication are aware of the fact that as the value of the resistance 37 between plate and grid of the reactance tube 29 becomes many times (ten or more) greater than the reactance of condenser 35, the phase quadrature relation between the grid to cathode voltage and plate to cathode voltage is approached. In order to increase the loading of the reactance tube 29 across L, it is only necessary to decrease the phase angle of said relation. This may be done by decreasing the value of the resistance 37, or by increasing the ratio of resistor 36 to resistor 37, or by merely increasing the resistance of resistor 36.

The screen grid 45 of reactance tube 29 may be connected to a suitable potential source +S through a resistor 43 whose upper end, as seen in Fig. 1, is bypassed to ground by condenser 44 for I. F. currents. Resistor 43 is necessary to prevent shorting out the I. F. signal across tuned circuit 11 and 12, and must be large enough not to load this circuit. The lower end of resistor 43 is bypassed to wire 41' through an I. F. bypass condenser 42. Cathode bias resistor 41 is bypassed to wire 41' by condenser 46.

The magnitude of the plate to cathode impedance of tube 29 is varied in order to adjust the simulated coupling means L. This is accomplished by varying the transconductance (G_m) of tube 29. Grid 33 is connected by lead 38 and resistor 39 to the slider of a potentiometer 24. The slider includes a resistor 25 which is returned to the grounded end of potentiometer resistor 24 through resistors 28 and 26 arranged in series. The upper end of resistor 24 may be connected to a negative direct current voltage supply terminal of suitable potential. The resistor 39 and bypass condenser 40 function as a filter network to prevent any alternating voltage from being applied to the input electrodes of reactance tube 29. Resistor 39 should be large so that it will have no loading effects on circuits 10, 9, L, 11, 12.

It will be appreciated that adjustment of the slider of potentiometer 24 will vary concurrently the effective negative bias of each of control grids 33 and 16 of the respective tubes 29 and 13. Since adjustment of potentiometer 24 results in control of the frequency response characteristic, or pass band, of the coupled circuits 10, 9 and 11, 12, the potentiometer is designated as the band width control. The adjustment of the band width control potentiometer results in a variation of the pass band width of coupled resonant circuits 10, 9 and 11, 12 for the following reasons.

The capacitative section (condenser 35) of the phase shifter causes the plate to cathode impedance of tube 29 to act like an inductance. Due to the resistor 36 between grid 33 and condenser 35, there will be introduced into the plate to cathode impedance of tube 29 a sufficient amount of resistance loading to maintain a flat top curve as the magnitude of L (the simulated inductance) is changed. The magnitude of bias resistor 41 is so chosen that with a suitable setting of the slider of potentiometer 24 there will be a normal transconductance value for tube 29. Hence coupling L will have a predetermined normal value.

Let it be assumed that such normal value of L provides sufficient coupling between circuits 10,

9 and 11, 12 to produce the solid line frequency response curve A of Fig. 2. The flatness of the top of curve A is produced by virtue of the resistance component introduced into the plate to cathode impedance of tube 29. The mid-band frequency F_1 may be 455 kc. The normal pass band width, by way of example, could be 15 kc. Changing the transconductance of tube 29 results in a change of the magnitude of L. Specifically, the magnitude of L is proportional to the reciprocal of transconductance. (See Hund, "Frequency Modulation," page 166 thereof, for this relation existing in a reactance tube of the type shown.)

Since L is an impedance common to both coils 9 and 11, increasing the loading across L increases the loading across coil 9 and 11. The resistance across L is inversely proportional to Gm thereby making the loading directly proportional to Gm. Similarly effective inductance L is inversely proportional to Gm thereby making the coupling directly proportional to Gm. In a pi section such as is provided by primary coil 9, coupling L and secondary coil 11, the magnitude of L is inversely related to the coefficient of coupling. If, for example, L is decreased, then the coupling between coils 9 and 11 increases. The coil L impedes the transfer of energy from coil 9 to coil 11. If the value of L is decreased, the impedance to flow of current from coil 9 to coil 11 is decreased. This is equivalent to saying that the coupling between the coils 9 and 11 is increased. Hence, both coupling and loading are directly proportional to the Gm of the reactance tube, and this is what is desired.

As the slider of potentiometer 24 is moved towards ground, for example, the negative bias on grid 33 is reduced thereby increasing the transconductance of the tube and decreasing inductance L. Since the coupling is approximately proportional to the reciprocal of inductance L, the band width may be increased from curve A to dash-line curve B. Concurrently the loading of the transformer 9, 11 increases thereby preserving the flat top of curve B. In the absence of any compensation, the mid-band frequency would shift to a somewhat higher value F_2, the frequency shift being approximately proportional to the reciprocal of L.

The undesired frequency shift from F_1 to F_2 is compensated for by a change in the input capacitance C (shown as a dotted line condenser) of the amplifier tube 13. The effective value of capacitance C is increased upon moving the potentiometer slider towards ground, because the transconductance of tube 13 is increased. Increase of the capacitance of C causes the mid-band frequency F_2 to be lowered back substantially to frequency F_1. Changing the value of C across the circuit 11, 12 changes the mid-band frequency, because the secondary 11 of the transformer 9, 11 is coupled to the primary 9 at or near critical coupling by means of L. Critical coupling provides a substantially flat-topped curve. When two resonant circuits of like frequency are coupled near critical, or tighter, then tuning of one circuit influences the tuning of the other. Hence, the effective response curve is now the curve C, shown in Fig. 2 as a dot and dash curve.

In other words, concurrently with change of effective inductance L to increase the pass band width of the selector network, the magnitude of capacitance C is changed sufficiently to maintain the mid-band frequency at the predetermined value of F_1. Of course, shifting the potentiometer slider towards the negative potential end of resistor 24 causes the value of L to increase thereby decreasing the coupling between circuits 10, 9 and 11, 12. This reduces the pass band width, but the transformer loading is reduced enough to preserve the flat top. The transconductance of tube 13 is reduced thereby to reduce the value of C. Hence, the mid-band frequency tends to be raised thereby compensating for the lowering of the frequency value due to the coupling being reduced. It will be seen that the change in the value of C is approximately proportional to the change in transconductance of tube 13. At the same time the frequency shift due to change in the value of L is approximately proportional to the transconductance of tube 29. Hence, the two frequency shifts are compensatory, and, being approximately proportional to transconductance, tend to maintain the value of F_1.

Typical radio frequency pentodes, suitable for use as tube 13, will provide an input capacity change in the order of 1 to 3 micromicrofarads (mmf.). In an I. F. amplifier network operating at 455 kc., such an input capacity (C) change would shift the mid-band frequency by about 5 kc., or 1%. At higher I. F. values it is possible to secure even greater percentages of frequency shift, if desired. At 5 mc. a 1% mid-band frequency change would be 50 kc., and would compensate for a band width change of 100 kc. When the circuit is suitably designed, changing the value of C, as L is changed, will maintain the mid-band frequency at F_1 regardless of pass band width.

It is to be understood that the potentiometer 24 is independent of the signals for providing selectable band-pass widths. Furthermore the band pass control is independent of the amplification of tube 4 even though they are energized from a common B+ source. If desired, however, the potentiometer may be replaced by a carrier-responsive source of negative bias. For example, a diode rectifier could be provided with a signal input circuit across the input transformer 1, the resulting rectified voltage being utilized to vary the transconductance of each of tubes 29 and 13 either in accordance with the carrier amplitude variation or in opposite relation. For automatic selectivity control, the gain of each of tubes 29 and 13 would be varied so as to provide an increase in the width of curve A in response to carrier amplitude increase. In FM reception the negative bias for the band width control could be derived from the rectified audio frequency signals. In that case the pass band width of the I. F. selector circuits would be directly proportional to the degree of modulation of the FM waves. Such a system is generally shown, for example, by J. Weinberger in U. S. Patent No. 2,230,563, granted April 21, 1942.

While we have indicated and described a system for carrying our invention into effect, it will be apparent to one skilled in the art that our invention is by no means limited to the particular organization shown and described, but that many modifications may be made without departing from the scope of our invention.

What we claim is:

1. In a variable-width band-pass amplification system for amplifying and passing alternating electric signals of a desired band of frequencies: signal input circuit elements including an amplifier and first parallel resonant circuit means connected for carrying the signals amplified by said

amplifier; second parallel resonant circuit means for carrying the signals passed by the system; each resonant circuit means having a high signal potential side and a low signal potential side; an electron-discharge-reactance-tube circuit forming the sole coupling between the resonant circuit means; said reactance-tube circuit including an electron-discharge reactance tube having a set of electron-discharge electrodes including an electron-emitting cathode, an electron-collecting electrode and an electron passage-controlling electrode; said electron-collecting electrode being connected to the high signal potential side of one of said resonant circuit means; said cathode being connected to the high signal potential side of the other resonant circuit means; phase-shifting elements also connecting said passage-controlling electrode to said first resonant circuit means to supply signals to said reactance tube for causing the reactance-tube circuit to present a signal impedance as the sole coupling between the resonant circuit means; variable bias supply means connected to said passage-controlling electrode to vary the impedance and change the response band width of the coupling; said amplifier including an electron-discharge tube also having a set of electron-discharge electrodes; and electron-discharge energizing means connected in parallel to the different sets of electron-discharge electrodes to energize the electron discharge of these tubes.

2. In a variable-width band-pass system for passing alternating electric signals of a desired band of frequencies from a signal input circuit to a signal output circuit: first parallel resonant circuit means connected as part of the signal input circuit for supplying the signals to be passed; second parallel resonant circuit means connected as part of the signal output circuit for carrying the signals passed by the system; each resonant circuit means having a high signal potential side and a low signal potential side; an electron-discharge reactance-tube circuit forming the sole coupling between the resonant circuit means; said reactance-tube circuit including an electron-discharge reactance tube having a set of electron-discharge electrodes including an electron-emitting cathode, an electron-collecting electrode and an electron passage-controlling electrode; said electron-collecting electrode being connected to the high signal potential side of one of said resonant circuit means; said cathode being connected to the high signal potential side of the other resonant circuit means; phase-shifting elements also connecting said passage-controlling electrode to said first resonant circuit means, to supply signals to said reactance tube for causing the reactance-tube circuit to present a signal impedance to the sole coupling between the resonant circuit means; variable bias supply means connected to said passage-controlling electrode to vary the impedance and change the response band width of the coupling; said phase shifting elements including resistance and capacitance connected to the high side of the first resonant circuit means and having a tap for supplying to the passage-controlling electrode reactance signals out of phase with respect to the signals in the first resonant circuit means by less than 90 degrees to provide a loaded variable inductive coupling impedance having resistive components proportioned to maintain the band-pass coupling approximately uniform across the pass band.

3. A variable-width band-pass system as defined by claim 2 in which the tap is from between two resistance portions of the phase shifting elements.

4. A variable-width band-pass system as defined by claim 1 in which the variable bias supply means is connected to be independent of the input signals, for providing selectable band-pass widths.

5. In a signal receiving system for receiving and utilizing alternating electric currents of a variable band-width in a desired band of frequencies; signal input means including first parallel resonant circuit means; signal utilizing structure including second parallel resonant circuit means, each resonant circuit means having a high signal potential side and a low signal potential side; and a variable band-width band-pass network including an electron-discharge reactance-tube circuit forming the sole coupling between the resonant circuit means; said reactance-tube circuit including an electron-discharge reactance tube having a set of electron-discharge electrodes including an electron-emitting cathode, an electron-collecting electrode and an electron passage-controlling electrode; said electron-collecting electrode being connected to the high signal potential side of one of said resonant circuit means; said cathode being connected to the high signal potential side of the other resonant circuit means; phase-shifting elements also connecting said passage-controlling electrode to said first resonant circuit means, to supply signals to said reactance tube for causing the reactance-tube circuit to present a signal impedance as the sole coupling between the resonant circuit means; variable bias supply means connected to said passage-controlling electrode to vary the impedance and change the response band-width of the coupling; said utilizing structure including a space-discharge amplification tube having input electrodes coupled to the second resonant circuit means to receive and amplify signals transferred; and said bias supply being connected to bias the amplification tube input electrodes simultaneously with the reactance tube passage control electrode for effecting variation of the inherent amplification tube input capacitance in the direction opposing the frequency-shifting tendency of the variations in coupling inductance on the mid-band frequency of the coupling band.

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