Nov. 15, 1938. A. W. BARBER 2,136,664

COUPLED CIRCUIT SYSTEM

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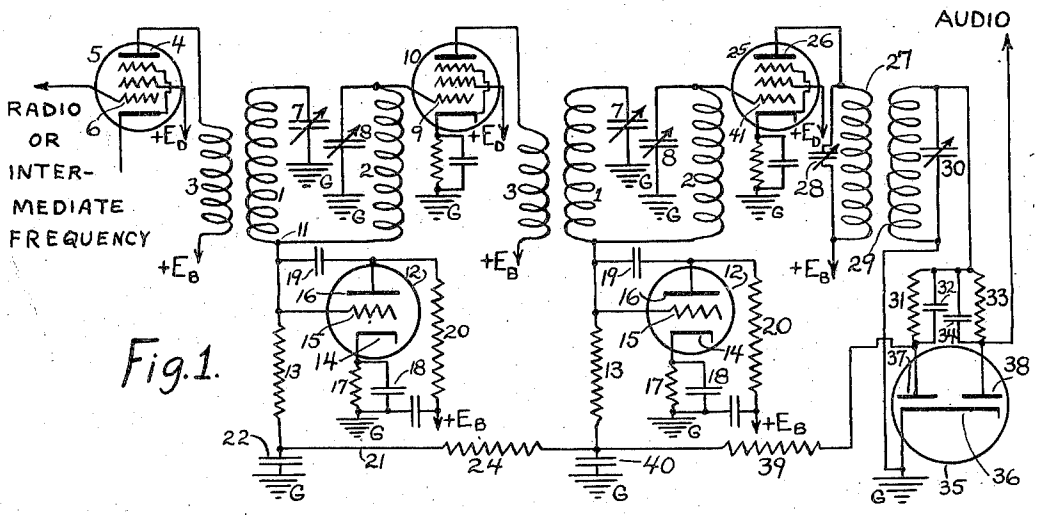


Fig. 1.

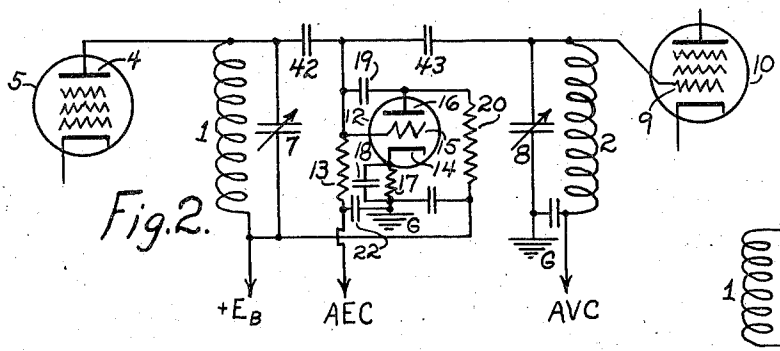


Fig. 2.

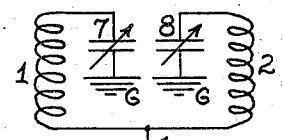


Fig. 3.

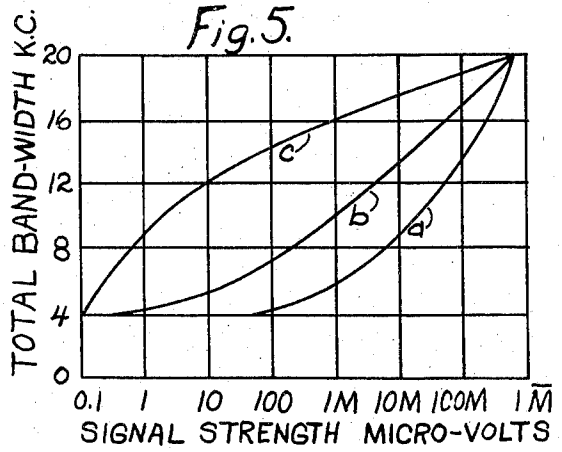


Fig. 5.

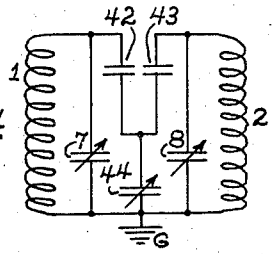


Fig. 4.

INVENTOR

Alfred W. Barber

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COUPLED CIRCUIT SYSTEM

Alfred W. Barber, Flushing, N. Y.

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17 Claims. (Cl. 179—171)

This present invention of mine concerns improvements in radio receiver circuits. It particularly relates to methods of, and means for, the automatic control of radio receiver fidelity as a function of the amplitude of the received signal by automatic control of selectivity in the radio or intermediate frequency amplifier circuits.

One object of my invention is to provide a coupled circuit in which the coupling may be controlled electrically. Another object is to provide in a radio or intermediate frequency amplifier, circuits coupled by electrically controlled coupling means. Still another object is to provide electrically controlled coupling means in connection with coupled circuits in a radio receiver whereby the band-pass characteristics of the receiver may be varied. A further object is to provide electrically controlled coupling means in the coupled circuits of a radio receiver wherein the electrical control operates from voltages generated by rectification of a received signal whereby the receiver response is controlled by the strength of the received signal. These and other objects will be set forth in detail in the following specifications.

Most radio and carrier wave receivers at the present time employ radio and intermediate frequency amplifiers consisting of cascaded thermionic vacuum tube amplifiers interconnected by means of systems of coupled circuits. In general these coupled circuits are capacity tuned to a desired frequency. The selectivity characteristics of each pair of circuits is determined by the power factor of the individual resonant circuits and the degree of coupling between circuits of a pair. With less than critical coupling, two circuits tuned to the same frequency will exhibit a single peak of maximum response. With more than critical coupling between circuits of a pair a double peaked or band-pass response is produced when each circuit is tuned to the same frequency. Until recently most receivers have been designed with very nearly critical coupling between interstage circuits in order to obtain maximum selectivity and gain. Such receivers, however, attenuate the higher modulation frequencies, the cut-off often being as low as 3000 cycles. The fidelity may be improved by over-coupling the receiver circuits but the better fidelity is usable only on strong signals. On weak signals interchannel interference is experienced with wide band response receivers. These considerations have led to the design of receivers having manually controlled circuit coupling for band expansion under favorable receiving conditions. In general the manual control is designed to vary the coupling from critical or a condition of maximum selectivity to something greater than critical giving a fifteen to twenty kilocycle band-pass response.

My present invention is concerned with means whereby the coupling between interstage circuits and hence the band-pass characteristics of a carrier wave receiver may be varied automatically in accordance with the strength of the received signal. A thermionic vacuum tube exhibits an input capacity which is a function of its plate to grid capacity and its grid to plate circuit gain. The plate to grid capacity may be the internal tube capacity plus wiring and stray capacities or these capacities may be enhanced by an additional discrete capacity connected between plate and grid. With a resistance as a plate load the effective input capacity to the tube is approximately the tube gain plus one times the sum of all plate to grid capacities. Since the gain of the tube may be varied by means of the grid bias, this input capacity may be controlled by means of the grid bias. My invention consists essentially in using this tube input capacity as a coupling impedance between interstage tuned circuits and in controlling the impedance and hence the coupling automatically by means of the voltage generated by rectification of the amplified signal. Since the capacity may be electrically controlled by grid bias control, the coupling and hence the selectivity or band-pass characteristics of the coupled circuits and the receiver may be electrically controlled.

One method which I employ in coupling two circuits is to place this controlled capacity in series with the two inductances of the coupled circuit and ground. Another method which I have used is to place the controlled capacity in a common path with part or all of the capacity of the tuning condensers of the two circuits. In order to control the coupling and hence the selectivity or band-pass characteristics of such coupled circuits in accordance with the strength of the received signal, I derive at least a part of the coupling tube bias from voltages derived from the rectification of the signal traversing the system. This control voltage may be the same voltage that is used for automatic volume control in the receiver or it may be a separately derived voltage. Any or all of the radio or intermediate frequency circuits of a carrier wave receiver may be thus automatically controlled and the characteristics of the receiver varied over wide limits.

The appended claims set forth, in particular,

the novel features to be found in this invention. The following description, however, when taken in connection with the drawing, will serve to set forth the theory and mode of operation of my invention.

In the drawing,

Fig. 1 shows a carrier wave amplifier circuit embodying one form of my invention.

Fig. 2 shows an interstage coupling circuit embodying another form of my invention.

Fig. 3 shows a pair of coupled circuits equivalent to the coupling accomplished in Fig. 1.

Fig. 4 shows the equivalent circuit of Fig. 2.

Fig. 5 shows a series of curves useful in explaining the operation of my invention.

Fig. 1 shows the application of my automatic control, in one form, to two stages of a radio or intermediate frequency amplifier. This amplifier may be a part of a tuned radio frequency, superheterodyne or other type of carrier wave receiver or amplifier. The interstage circuit consists of a coil 1, which we may call the primary coil, and a coil 2, which we may call a secondary coil. Primary coil 1 receives a voltage from coil 3 coupled inductively to it and connected to plate 4 of the tube 5. Tube 5 derives an input on grid 6 from preceding circuits. Coil 1 is tuned by condenser 7 and coil 2 is tuned by condenser 8. The voltage across coil 2 is applied to grid 9 of the following amplifier tube 10. The coupling impedance between coils 1 and 2 is placed between their common junction point 11 and ground G. This coupling impedance consists of the input impedance of tube 12 which is predominantly a capacity reactance. Tube 12 comprises a cathode 14, a control grid 15 and a plate or anode 16. A cathode current bias resistor 17 by-passed by condenser 18 is provided to give the tube an initial bias although other bias means may be used. A condenser 19 is shown between grid 15 and plate 16 which may be taken to represent the sum of the internal and external plate to grid capacity. Resistor 20 in the circuit of plate 16 is provided as a gain producing load.

The input capacity between grid 15 and ground G is approximately equal to the capacity 19 times the grid to plate gain of the tube plus one. The gain of the tube is a function of the value of resistor 20 and the net bias on grid 15. If a bias is supplied to grid 15 thru resistor 13 by means of lead 21, 22 being a by-pass condenser, the gain of the tube 12 is altered in accordance with the bias and the effective input capacity is altered. Making the externally applied bias more negative decreases the gain of tube 12 and decreases its effective input capacity. With no externally applied bias the effective input capacity may be twice or more the capacity of condenser 19 while at a cut-off bias the input capacity will be equal to the capacity of condenser 19. Since the coupling between coils 1 and 2 is the common impedance of the input capacity of tube 12, the smaller this capacity the greater the coupling between the coils 1 and 2. Fig. 3 shows an equivalent circuit with variable condenser 23 as the common coupling impedance. In Fig. 1 condenser 19 may be chosen as the maximum desired coupling impedance to give maximum band-pass. In one case I found that a band-pass of twenty kilocycles was produced with condenser equal to 1000 micro-microfarads. At cut-off bias on grid 15 the effective coupling impedance will be equal to the capacity of condenser 19. Resistor 20 may be chosen so that at zero external applied bias, the gain of tube 12 increases the coupling capacity and hence reduces the coupling impedance to give the desired minimum band-pass. Thus by a change in grid bias on tube 12 the coupling and band-pass may be varied between almost any desired limits.

The same band-pass control system is shown between tubes 10 and 25 as was described in connection with tubes 5 and 10.

The expansion control voltage is generated by rectification of the amplifier output. Tube 25 feeds a coil 27 tuned by condenser 28 thru its plate 26. Detector tube 35 receives an input from coil 29 coupled to coil 27 and tuned by condenser 30. Detector 35 comprises a cathode 36 and anodes 37 and 38. Cathode 36 is connected to one end of coil 29 and ground G. The other end of coil 29 feeds anodes 37 and 38, anode 37 thru the output load consisting of resistor 31 by-passed by condenser 32 and anode 38 thru the output load consisting of resistor 33 by-passed by condenser 34. The resistor 33 condenser 34 load may be made suitable for generating audio demodulation products and the drop may be applied to an audio amplifier or output device. Resistor 31 and by-pass condenser 32 should form a load only to very low frequencies and direct current thereby developing a voltage drop suitable for automatic volume and other control purposes. Since anode 37 will become negative with respect to ground when a signal is received, the polarity is correct for automatic coupling control as well as automatic volume control. This negatively increasing voltage which is generated upon receiving a signal may be applied to grids 15 by means of the coupling and filtering resistors 39 and 24 and condensers 40 and 22 and thru the grid resistors 13. The greater the magnitude of the received signal, the greater the negative voltage generated and applied to the coupling tubes and the smaller the coupling capacity and the greater the coupling and band-pass.

It will be noted that the same control bias is applied to the control grids 15 of the coupling control tubes 12 and to the control grids 9 and 41 of the amplifier tubes 10 and 25, thru the coils 2, thus producing automatic band-width and volume control from the same control voltage. A wide range of modifications are possible as for instance a different bias may be applied to the amplifiers and one which varies in a different way from the bias applied to the coupling tube grids. One method of making the amplification control different from the coupling control is to use different cathode resistor combinations in the amplifier and coupling tube circuits. Delayed control may be applied to the amplifier or coupling tubes or both by means of a bias applied to the detector which prevents rectification until the input signal reaches a predetermined value.

Fig. 5 shows several curves of "total band-width in kilocycles" vs. "signal strength in micro-volts." Curve *a* shows an automatic expansion characteristic obtained with delayed coupling control bias. No expansion takes place until the received signal reaches 100 micro-volts from which point the expansion increases reaching a maximum at about 170,000 micro-volts. Curve *b* shows a curve of expansion resulting from no bias delay while curve *c* shows an initial rapid increase in expansion due to a control tube with a different grid control characteristic. For present general receiving conditions a curve similar to *a* seems most satisfactory with the amount of delay depending on local conditions.

Fig. 2 shows an expansion circuit as applied to an interstage coupling system in which the coupling impedance is a capacity common to part or all of the tuning capacity of two tuned circuits. An input or primary coil 1, tuned in part by condenser 7, is connected to plate 4 of tube 5. The output or secondary coil 2 is tuned in part by condenser 8 and feeds grid 9 of a following tube 10. The completion of the tuning of coil 1 is accomplished by condenser 42 in series with the input capacity of coupling tube 12 while the tuning of coil 2 is completed by condenser 43 in series with the input capacity of coupling tube 12. Thus the input capacity of tube 12 is common to a part of the tuning capacity of coils 1 and 2 and thus forms a common coupling impedance between the coils. Although different values of condenser 19 and resistor 20 may be used in this circuit, the coupling action is similar to that described in connection with Fig. 1. The greater the input signal, the greater the bias on tube 12 and the smaller its input capacity. The smaller the input capacity the greater the degree of coupling between coils 1 and 2 and the greater the band-pass width of response. Grid 9 of the amplifier tube 10 is indicated as controlled by an automatic volume control voltage thru coil 2. Grid 15 and hence the band-pass width is controlled by a separate voltage marked AEC to denote "automatic expansion control" thru grid resistor 13. The expansion and volume control voltages may be separately generated and may vary in different ways as functions of the signal strength or they may be the same as voltage generated as shown in Fig. 1.

The circuit shown in Fig. 4 is equivalent to the circuit of Fig. 2. Coil 1 is tuned by condenser 7 in parallel with condensers 42 and 44 in series while coil 2 is tuned by condenser 8 in parallel with condensers 43 and 44 in series. Thus condenser 44 being common to both tuned circuits forms a common coupling impedance. In Fig. 2 the input capacity of tube 12 replaces coupling condenser 44 of Fig. 4.

While I have described only a few systems whereby my invention may be carried into effect and have pointed out a few possible variations, it will be apparent to one skilled in the art that many modifications are possible without departing from its spirit and scope as set forth in the appended claims.

What I claim is:

1. In a radio receiver, an intermediate frequency vacuum tube amplifier including the combination of two resonant circuits between each pair of amplifier tubes and means for coupling said two resonant circuits comprising an impedance common to said two resonant circuits, said impedance comprising the input impedance of a thermionic vacuum tube.

2. The combination as set forth in claim 1 in which the input impedance of said coupling tube is controlled by the amplitude of the signal traversing said amplifier.

3. In a radio receiver, the combination of interstage selective means and interstage coupling means, said interstage selective means comprising pairs of resonant circuits and said coupling means comprising the input capacities of thermionic vacuum tubes connected mutually in series with circuits comprising each pair.

4. The combination as set forth in claim 3 and including means for controlling said input capacities as a function of the amplitude of signals traversing said receiver.

5. In a carrier wave amplifying system, the combination of a plurality of thermionic vacuum tube repeaters, interstage selective means comprising pairs of tuned circuits, mutual coupling impedances between said circuits comprising each pair, a rectifier receiving amplified waves traversing the system, said rectifier generating a unidirectional voltage proportional to the amplitude of said waves, in which each of said coupling impedances comprises the input impedance of a thermionic vacuum tube and conductive means between said rectifier and the control grids of said coupling tubes.

6. In a carrier wave amplifier, the combination of at least two tuned circuits and a coupling impedance common to at least a part of said two tuned circuits in which said common impedance comprises the grid to cathode impedance of a thermionic vacuum tube.

7. In a carrier wave amplifier, the combination of at least two tuned circuits and a coupling impedance comprising the control grid to cathode impedance of a thermionic vacuum tube, in which each tuned circuit comprises a coil and condenser, one end of each condenser being connected to one end of each coil, the other end of each condenser being connected to ground, the other end of each coil being connected together and to said control grid.

8. The combination as set forth in claim 7 and including a condenser connected between plate and grid of said vacuum tube and a resistor in the plate circuit of said tube.

9. The combination as set forth in claim 1 and including means applying a bias to said control grid at least a part of said bias being a function of the amplitude of signals traversing said amplifier.

10. In a carrier wave amplifier, the combination of at least three thermionic vacuum tube repeaters each including at least a cathode, control grid and plate, a tuned circuit connected between the plate of the first of said repeaters and a source of direct current voltage, a second tuned circuit connected between the control grid of the second of said repeaters and ground, and a condenser connected between the plate of said first repeater and the control grid of the third of said repeaters and a second condenser connected between the grid of said second repeater and the control grid of the third of said repeaters.

11. The combination as set forth in claim 10 and including a rectifier receiving the output of said amplifier and conductive means between said rectifier output and the grid of the third of said repeaters.

12. The combination as set forth in claim 10 and including a rectifier receiving the output of said amplifier, conductive means between said rectifier and the grid of the third of said repeaters and additional means comprising a resistor in the circuit of the plate of the third of said repeaters.

13. In a carrier wave receiver, the combination of a carrier wave amplifier comprising a plurality of thermionic repeater tubes and interposed pairs of tuned circuits, a carrier wave rectifier including an output circuit and coupling impedances between said tuned circuits forming said pairs, in which said coupling impedances comprise the grid to cathode impedance of thermionic vacuum tubes, direct current conductive means interconnecting said rectifier output circuit and said coupling impedance tube grids.

14. In a carrier wave receiver, the combination

of at least two thermionic vacuum tube repeaters, a tuned circuit associated with the output circuit of one of said repeaters and a second tuned circuit associated with the input of another of said repeaters, a coupling impedance common to at least a part of the impedance of said output and input tuned circuits, a rectifier receiving the output of the last of said repeaters and including a direct current output load circuit, in which said coupling impedance comprises the grid to cathode impedance of a thermionic vacuum tube and conductive means interconnecting said grid and said rectifier output circuit.

15. The combination as set forth in claim 14 wherein the net bias on said grid is the sum of the drop across said rectifier output circuit and the cathode current drop in a resistor connected between said cathode and ground.

16. In a selective carrier wave amplifier, means for varying the selectivity of said amplifier comprising a pair of capacity tuned circuits, means for passing a fractional part of the capacity current in said tuned circuits thru a common impedance comprising the input capacity of a thermionic vacuum tube and means for varying said input capacity as a function of the amplitude of signals traversing said amplifier.

17. A system as set forth in claim 16 wherein said means for passing a fractional part of the capacity current in said tuned circuits comprise electrical condensers having capacities small compared to the total tuning capacity of said tuned circuits.

ALFRED W. BARBER.