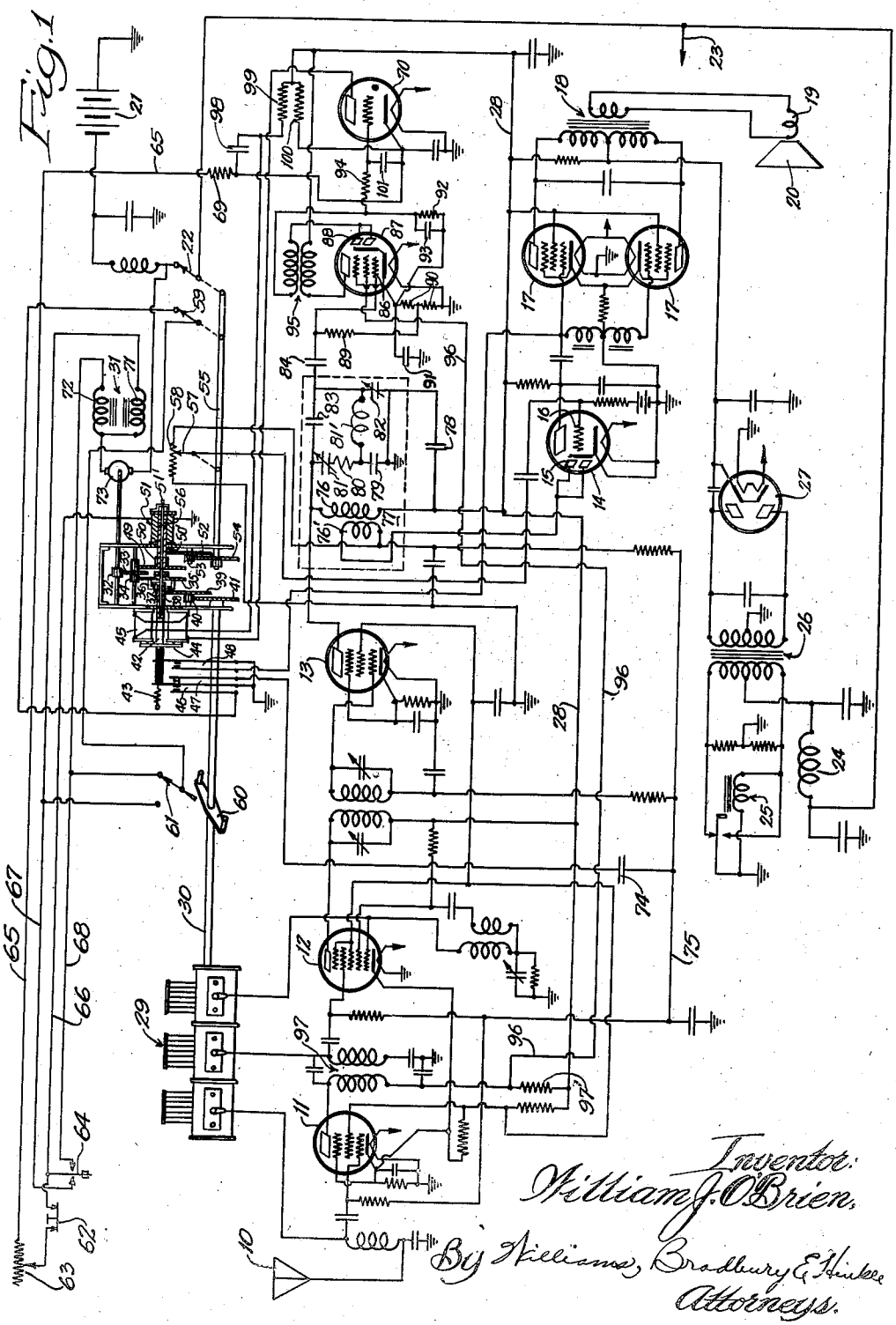
Aug. 26, 1947. W. J. O'BRIEN 2,426,580

RADIO RECEIVER

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Fig. 1



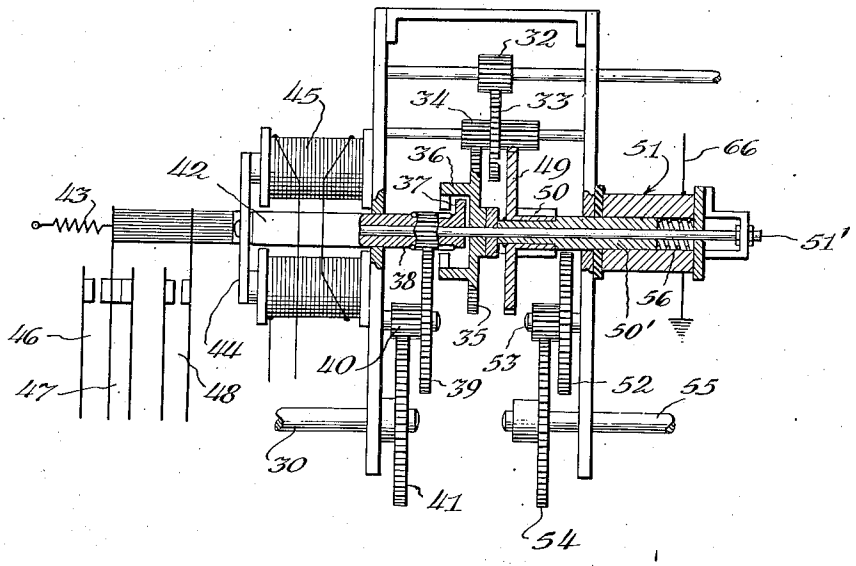
Inventor:
William J. O'Brien,
By Williams, Bradbury & Hinkle
Attorneys.

Aug. 26, 1947. W. J. O'BRIEN 2,426,580

RADIO RECEIVER

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Fig. 1.A.



Inventor:
William J. O'Brien
By Williams, Bradbury & Hinkle
Attorneys

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RADIO RECEIVER

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Fig. 4.

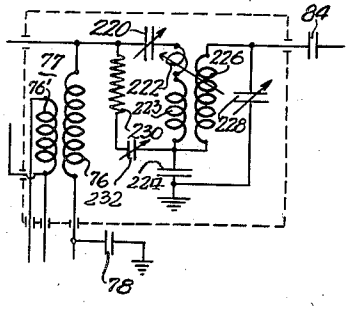


Fig. 3.

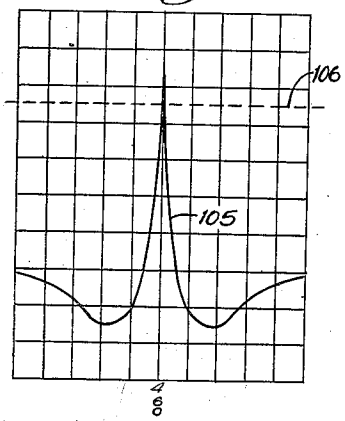
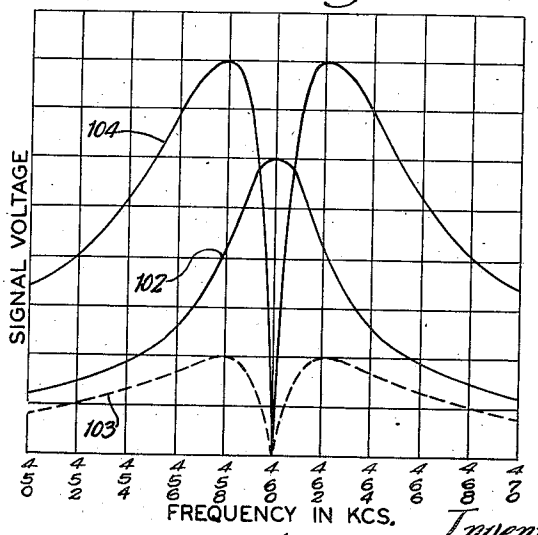


Fig. 2.



Inventor:
William J. O'Brien,
Williams, Bradbury & Hinkle
By
Attorneys.

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2,426,580

UNITED STATES PATENT OFFICE

2,426,580

RADIO RECEIVER

William J. O'Brien, Chicago, Ill., assignor to Edward F. Andrews, Chicago, Ill.

Application April 10, 1941, Serial No. 387,907

30 Claims. (Cl. 250—20)

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This invention relates to the tuning of radio apparatus, and particularly to radio receivers embodying tuning devices of the stop-on-carrier type such as those described and claimed in the co-pending applications of Edward F. Andrews, Serial No. 219,713, filed July 18, 1938 (Patent No. 2,262,218, granted November 11, 1941), and Serial No. 275,437, filed May 24, 1939 (Patent No. 2,326,-737, granted August 17, 1943). Certain features disclosed in the present application are also disclosed and claimed in my copending divisional application Serial No. 681,183, filed July 3, 1946.

This invention relates to means for improving the rapidity of action, the accuracy of tuning, and the discrimination in favor of the desired signal in radio receivers having stop-on-carrier tuning, and for otherwise improving such devices.

The invention further relates to the drive mechanism for regulating the volume and effecting stop-on-carrier tuning in automobile sets or home sets, either from a remote point or otherwise.

The invention relates also to a new and improved circuit arrangement for discriminating between signals covering broad and narrow frequency bands.

One of the objects of this invention is to provide an improved radio receiver of the stop-on-carrier type.

Another object of this invention is to provide an improved means for tuning or adjusting the frequency of radio apparatus.

A further object is to provide a stop-on-carrier tuning circuit which shall be extremely sharp in its response so that the tuning means cannot be stopped except very close to the perfectly tuned position.

A further object is to provide means for effecting sharply tuned, fast-acting stop-on-carrier tuning, actuable by carrier signals of a definite narrow frequency, and relatively unresponsive to broader signals.

A further object is to provide a new and improved circuit arrangement for discriminating between signals covering broad and narrow frequency bands.

A further object is to provide a balanced and phased circuit which effects a strong change in the effective signal strength only quite exactly at resonance.

A further object of the invention is to provide a balanced and phased circuit supplying a signal voltage having a magnitude dropping extremely rapidly as resonance is approached, and which, when combined with a signal of more nearly constant magnitude at resonance and of opposite

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polarity, causes the operation of relay means to stop the tuning means only when a definite carrier frequency is quite exactly tuned in.

A further object is to combine the balanced and phased sharply responsive circuit with the circuits of a radio receiver to produce a well coordinated arrangement for improving the tuning of the receiver.

A further object of the invention is to provide a device to facilitate the tuning of radio signals having selective means supplying a maximum control voltage at intermediate frequency, further selective means supplying a second control voltage opposing the first and having a maximum value at a frequency slightly displaced from the intermediate frequency and a minimum value at the intermediate frequency, and a grid controlled electron tube adapted to be rendered conductive by the first control voltage only when the opposing control voltage is close to its minimum value.

Other objects and advantages of the present invention will become apparent from the ensuing description, in the course of which reference is had to the accompanying drawings, in which:

Fig. 1 diagrammatically illustrates one embodiment of the invention;

Fig. 1—A is a fragmentary enlarged view of a portion of the apparatus shown in Fig. 1.

Fig. 2 is a graphic representation of certain control voltages obtaining in the embodiment of Fig. 1, and in other embodiments;

Fig. 3 is a graphic representation of the resultant of two of the control voltages illustrated in Fig. 2; and

Fig. 4 is a partially diagrammatic view of another embodiment of the invention.

Referring to the drawings, Fig. 1 depicts a standard automobile superheterodyne receiver to which elements of my invention have been added. The receiver comprises an aerial 10, a radio frequency tube 11, a first detector and oscillator 12, an intermediate frequency tube 13, a tube 14 comprising a diode section 15 and an audio amplifier section 16 and two power amplifier tubes 17 connected in push-pull relation. The output of the power tubes 17 is connected through a transformer 18 to the voice coil 19 of a speaker 20.

Energy is supplied by a battery 21 adapted to be connected by a switch 22, illustrated in circuit closing position, to the cathode heater circuit 23, the speaker field coil 24, and to an interrupter 25. The interrupter 25 controls the flow of current through the primary of a transformer 26, the secondary of which is connected to a rectifier

tube 27 which supplies B current to a B supply line 28.

The receiver is tuned by means of a gang of condensers 29 operable by a shaft 30. The gang of condensers is adapted to be driven by a reversible motor 31 through pinions 32, 33, 34, 35, clutch elements 36 and 37, and pinions 38, 39, 40, and 41, the latter being rigidly mounted on the shaft 30. The clutch element 37 and the pinion 38 are mounted on an axially movable and rotatable shaft 42 which is normally biased to the left, as viewed in Fig. 1, by a spring 43. The shaft 42 is movable to the right, as viewed in that figure, by an armature 44 (with respect to which it is rotatably mounted) upon energization of a fast acting relay 45 constructed and arranged in circuit relative to a gas type control tube in a manner specifically set forth and claimed in my copending application, Serial No. 387,908, filed contemporaneously herewith. The clutch elements 36 and 37 are in engagement when the relay 45 is deenergized, and are disengaged when the relay is energized—the elements being shown in disengagement better to illustrate the construction. The armature 44 controls the operation of switches 46, 47, and 48. Switches 46 and 48 are closed and switch 47 is open when the relay 45 is deenergized. When the relay 45 is energized, switch 47 is closed and switches 46 and 48 are open, as shown in Fig. 1.

The pinion 34 meshes with a gear 49, which is rigidly secured to the pinion 50, the gear 49 and pinion 50 being mounted on the rotatable armature 50' of a solenoid 51. The pinion 50 and armature 50' are rotatable about a shaft 51' supported by a suitable bracket and the inner end of shaft 42, which is made hollow so as to receive the shaft 51' and so as to be movable relative thereto by solenoid 45. When the solenoid 51 is energized, the pinion 50 meshes with a gear 52 which is connected through gears 53 and 54 to a shaft 55. When the solenoid 51 is deenergized, a spring 56 forces the gear and pinion 49 and 50 to the left, as viewed in Fig. 1, so that the pinion 50 is moved out of mesh with the gear 52. It will be understood that a clutch similar to the clutch 36 and 37 may be employed to connect the the pinion 50 to the gear 52 instead of the meshing and unmeshing of the gears, if desired. The shaft 55 actuates the movable arm 57 of a volume control potentiometer 58 and also actuates the power switch 22 and a motor circuit controlling switch 59.

The shaft 30 carries an abutment member 60 which is adapted to throw a two-way limit switch 61 from one position to the other at the limits of movement of the condensers 29. As will hereinafter be readily understood, the throwing of the switch 61, which is connected to switch 59, reverses the direction of rotation of the motor 31 so that the condensers move back and forward from one extreme position to the other, and vice versa, until the motor is stopped when a carrier is received.

The receiver is adapted to be controlled from a remote position by means of a remote control unit which comprises the elements in the extreme left hand top corner of Fig. 1. The remote control unit comprises a normally closed switch 62, a sensitivity controlling rheostat 63, and a single pole, double throw power and volume control switch 64 which is resiliently biased to a normally open intermediate position, in which it is shown. One side of the rheostat 63 is connected to a conductor 65, and the other to one side of the switch 62. The other side of the switch 62 and also the movable blade of switch 64 are connected to a conductor 66. One contact of the switch 64 is connected to a conductor 67, and the other contact is connected to a conductor 68. The conductors 65, 66, 67 and 68 may be in the form of a cable of any desired length so that the radio receiver may be controlled from any distance. Thus, the remote control elements described may be located on the dashboard or on the steering column of the steering wheel of an automobile, and the remainder of the receiver may be located the rear end of the automobile, for example in the rear baggage compartment, away from the source of electrical disturbance created by the generator and ignition system of the engine.

The conductor 65 is connected through a resistance 69 to the cathode of a gas type control tube 70. The conductor 66 is connected to one side of the solenoid 51, the other side of the solenoid being grounded. The conductor 67 is connected to one of the contacts of the limit switch 61 and to one winding 71 of the motor 31. The conductor 68 is connected to the other contact of the limit switch 61 and also to the other winding 72 of the reversible motor 31. The other sides of both windings are connected to the armature 73 of the motor through one of its branches, the other side of the armature being connected through the other brush to the battery 21.

The movable blade common to switches 46 and 47 and the movable blade of switch 48 are grounded. The fixed blade of switch 47 is connected through condenser 74 to the automatic volume control lead 75 and the fixed blade of switch 48 is connected to the control grids of power tubes 17. It will be readily understood that when these control grids are grounded by closure of switch 48, the receiver is muted.

The plate of the tube 13 is connected to one terminal of the primary 76 of a closely coupled transformer 77, the other terminal of which is connected to the B supply lead 28. The secondary 76' of this transformer is connected to the plates of the detector diode 15, and also to the volume control resistor 58 and the AVC control lead 75.

The primary 76 forms part of a tank circuit which includes condenser 78, condenser 79, resistance 80, and an adjustable condenser 81, whereby this tank circuit may be tuned to intermediate frequency. The condenser 79 also forms part of a tank circuit which includes the condenser 79, an inductance coil 81', and an adjustable condenser 82, whereby this circuit is tuned to intermediate frequency. The common side of the three condensers 78, 79 and 82 is grounded. The common side of the primary winding 76 and condenser 81 is connected through a condenser 83 to the common side of the inductance 81' and condenser 82 and to a condenser 84. The condenser 84 is connected to the control grid 86 of the pentode section of tube 87, which also includes diode section 88. The control grid is also connected through a resistance 89 to an intermediate point of a resistance 90. One side of the resistance 90 is grounded, the other being connected to the cathode of the pentode section of tube 87. This cathode is connected to one side of the condenser 91 by-passing resistance 90 and also to a resistance 92, which is shunted by a very small condenser 93. The faster the speed of operation of the tuning condensers 29, the smaller should be the capacity of condenser 93. The resistance

92 and the condenser 93 are connected through a resistance 94 to the grid of the gas tube 70 and also to one terminal of the secondary of a transformer 95, constructed and arranged so that the coupling between the primary and secondary may be varied, the other terminal of which is connected to the plate of the diode elements 88. The screen grid of the pentode section of tube 87 is connected by a conductor 96 to the plate circuit of the tube 11 at a point between the primary of the transformer 97 and the resistance 97', which connects the plate to the B supply line 28.

One side of a condenser 98 is connected to the cathode of the tube 70 and the other side to a resistance 99, which is in turn connected to the B supply line 28. The condenser 98 supplies a large flow of current through the relay 45 when the gas tube 70 is ionized while the resistance 99 limits the steady flow of current through the relay 45.

The cathode of the gas tube 70 is connected through a bleeder resistance 100 to the B supply line 28. The plate of the pentode section of tube 87 is connected through the primary of the transformer 95 to the B supply line 28. The cathode and grid of the gas tube 70 are connected through a condenser 101 which provides, with the resistance 94, a time delay circuit which delays the effect of the ionizing voltage on the grid of the gas tube 70.

When the receiver is out of operation, the switches 22 and 59 are in circuit opening positions and relay 45 and solenoid 51 are de-energized. When it is desired to place the receiver in operation, the movable blade of the volume control switch 64 is moved to the left. This completes a circuit from the battery 21 through armature 73, winding 71, conductor 67, the switch 64, conductor 66, solenoid 51, and through ground back to the battery. The energization of the solenoid connects the gears 50 and 52 so that the shaft 55 is driven in the volume increasing direction, closing switches 22 and 59. At the same time, the relay 45 being de-energized, the condensers 29 are driven through the clutch 36—37. After the set is turned on, the switch 64 is released and the motor operates first in one direction and then in the other, as determined by the limit switch 61. In one direction of operation motor winding 71 is energized, and in the other, winding 72 is energized, the windings being alternately connected across the battery through circuits including switch 59, the position limit switch 61 and the grounding switch 46. Upon release of switch 64 the solenoid 51 is de-energized to terminate operation of the volume control.

The backward and forward movement of the condensers continues until the tubes have warmed up and a station is received. When a station is received, automatic volume control voltage is supplied from the diode detector 15 to line 75, from whence it is applied to the grids of the tubes 11, 12 and 13. As a result of the application of this automatic volume control voltage on the grid of the radio frequency tube 11, the plate current of the tube is decreased, and the voltage drop across resistance 97' is decreased. Consequently, a more positive voltage is applied to the screen of the pentode section of tube 87 through conductor 96. The voltage thus applied to the screen has a value which follows approximately the contour of curve 102 in Fig. 2 as the signal being tuned in approaches

resonance with the I. F. circuits of the receiver, this voltage rising rapidly as a station is being tuned in and reaching a maximum when a station is exactly tuned in. As a result of the increase of the voltage on the screen grid, the plate current of the pentode section of tube 87 increases, and the potential drop across the resistance 90 increases. Consequently, a corresponding voltage is applied through resistances 92 and 94 upon the grid of the gas tube 70. The voltage thus applied to the grid of the gas tube is depicted by the curve 102 on Fig. 2, which indicates the variation of the voltage with respect to frequency.

The primary 76 of the transformer 77, condenser 81, resistance 80, condenser 79, large bypass condenser 78, and the mutual reactance of the condenser 83 constitute a tank circuit tuned to the intermediate frequency. Condenser 79, inductance 81', condenser 82, together with the mutual reactance of the condenser 83, also constitute a tank circuit tuned to intermediate frequency. This circuit is excited through condenser 79 and also through condenser 83. The coupling of these tank circuits through condenser 79 is inversely proportional to the frequency, while the coupling occurring through the condenser 83, which energizes coil 81', which is energized by a portion of the primary tank circuit current flowing through condenser 83, is proportional to the frequency. Due to these opposing electrostatic and electromagnetic couplings and the parameters of the elements of the two tank circuits, when a signal of exactly intermediate frequency is received by the primary 76, the potential across the condenser 82 is a minimum. In other words, the effect of the coupling occurring through condenser 83 produces a voltage drop across the inductance 81' which is equal and opposite to the voltage drop occurring across the condenser 79 at resonance. The value of the resistor 80 is selected so as to bring the voltage across the condenser 79 one hundred and eighty degrees out of phase with the voltage across the coil 81'. Under these conditions, there will be substantially zero voltage across the condenser 82 at resonance. Considered in another light, the electromagnetic and electrostatic couplings are balanced or neutralized, i. e., the inductive and capacitative reactive components are made to balance or neutralize. There remains a resistive component of coupling which can be balanced or neutralized only by a resistive component supplied, in the arrangement described, by the resistor 80. In one aspect the arrangement of the coupled circuits may be considered as a balanced bridge circuit or a circuit providing zero coupling at resonance.

On the other hand, if the signal received by the primary 76 is slightly out of resonance, there is no longer a balance between the opposing couplings; that is, the effect of one coupling is greater than that of the other, and a potential varying with the departure from the resonance frequency exists across the condenser 82. The variation of the voltage across the condenser 82 with frequency is indicated diagrammatically in the curve 103 of Fig. 2. Thus, it will be seen that when a station is accurately tuned in, no signal (or a minimum signal in case the balance between the two tuned circuits is not quite exact) is applied to the control grid 86 of tube 87. When the variable condensers 29 are ap-

proaching exact tuning, that is, two or three kilocycles away from exact tuning, a very large alternating current voltage is applied to the grid 86 and a correspondingly large alternating current voltage is induced in the secondary of the transformer 95. This voltage is rectified by the diode section of tube 87 and causes a voltage drop across resistance 92, the plate or negative side of which is connected to the grid of the gas tube through resistance 94 to apply a negative voltage to that grid. The variation of the negative voltage applied to the grid of the gas tube with respect to frequency is shown by the curve 104 of Fig. 2. It will be understood that the curve 104 generally corresponds to the curve 103 after amplification in the pentode section and rectification by the diode section 88 of tube 87. The height or magnitude of the single peaked relative to the double peaked control voltage is controllable by varying the coupling of the transformer 95.

Referring again to Fig. 2, it will be seen that a resultant voltage equal to the algebraic sum of the positive direct current voltage represented by the curve 102 and the negative direct current voltage represented by the curve 104 is applied to the grid of the gas tube 70. The resultant voltage applied to the grid of the gas tube is definitely negative more than one kilocycle on each side of perfect tuning. This resultant voltage is depicted by the curve 105 in Fig. 3. When resonance is more closely approached, the positive voltage shown by curve 102 predominates, and the grid of the gas tube 70 becomes sufficiently positive to overcome the fixed negative bias on the grid of the gas tube resulting from the voltage drop across the resistances 69 and 63. The voltage at which ionization occurs may be some value, such for instance as that indicated by the dotted line 106 in Fig. 3, so that the gas tube is ionized only when the tuning means condensers are in position very closely to tune in a station. The tube 70 ionizes and its plate-cathode resistance drops to a low value. The condenser 98, which accumulates a high charge by reason of its connection to the B supply through the resistor 99 during deionization of the tube 70, now discharges rapidly through the relay 45, and the clutch elements 36 and 37 instantly disengage, thus terminating the drive of the condensers. At the same time, the switch 46 is opened to disconnect the motor from the battery. The steady current flow through the resistor 99 and relay 45 is sufficient to hold the relay closed after the condenser 98 is discharged. As the switch 46 is opened, the switch 48 is also opened. This disconnects the connection between the grids of the tubes 17 and ground which had previously muted the audio frequency output of the set. Thus, the audio output of the set can again be heard from the speaker 19. A further function performed by the relay 45 is to close the switch 47, thus connecting one terminal of the condenser 74, which was previously open circuited, to ground. This renders the condenser 74 effective to increase the time delay applied to the automatic volume control voltage which is required for proper quality during the audible reception of a signal.

The volume may be adjusted at any time by moving the movable blade of the volume control switch 64 to one side or the other. The solenoid 51 is thereby energized, operatively connecting the motor to the shaft 55, and the motor is energized and drives shaft 55 to move the arm 57 in the appropriate direction to increase or decrease the volume.

When it is desired to tune in a different station, the switch 62 is opened manually so that the cathode to ground connection of the plate circuit of the gas tube 70 is broken. The gas tube is thus de-ionized and the relay 45 is consequently deenergized, and the switch 46 closes so that the motor is put into operation. When the switch 62 is allowed to close again, the gas tube 70 will be re-ionized when a signal of adequate strength is received.

The grid bias of the gas tube 70 may be adjusted at will by means of the rheostat 63 so that the minimum strength of station to which the stop-on-carrier system will respond may be regulated at will.

It may be well briefly to review some of the outstanding advantages of the balanced bridge or zero coupling at resonance circuit for stop-on-carrier tuning. This circuit produces a double peaked selectivity curve, as shown at 104 in Fig. 2, the signal voltage of which drops very sharply in the immediate vicinity of resonance. This very sharp change in signal strength with small frequency variations is not dependent on the rigorous elimination of resistance in the circuit, but is inherent in the circuit arrangement. It provides the extremely sharp selectivity desired by simple and inexpensive means. The phasing or balancing out of the effective resistance in the balanced bridge circuit produces a type of resonance curve in which the sides of the depression between the two peaks are straight and steep, coming practically to a point at the bottom so that voltage varies substantially linearly with respect to frequency. This curve is the selectivity curve of a tuned circuit with practically zero resistance, and it has the characteristic that the voltage falls practically to zero at the resonant frequency. With any appreciable effective resistance in the circuit, the bottom of the depression would depart more from linearity and the voltage would not fall near zero at resonance.

It may also be noted that the signal from the balanced bridge circuit does not itself cause the ionization of the gas tube, but prevents the ionization of this tube by the single-peaked control voltage illustrated by the curve 102 in Fig. 2, except in the immediate vicinity of resonance. As long as the voltage shown by the curve 104 has a certain appreciable value, the voltage shown by the curve 102 cannot effect ionization. Although it is the voltage shown by the curve 102 that causes ionization, still it is the voltage from the balanced bridge circuit shown by the curve 104 which determines when or at what frequency ionization is effected.

It should be noted further that with this arrangement, the gas tube cannot be ionized by a broad signal, but is responsive only to a signal of the required sharpness, such as that from a broadcasting station. A broad signal results in a high value of the voltage represented by the curve 104 wherever the voltage represented by the curve 102 is high. Thus, with a broad signal, the voltage 104 effectively prevents the ionization of the gas tube by the voltage 102. The gas tube will be ionized only when the signal is so sharp that the voltage shown by the curve 104 is low at the same frequency or at the same time that the voltage shown by the curve 102 is high. The ionization of the gas tube is thus not possible by broad electrical disturbances,

regardless of their intensity. On the contrary, the gas tube may readily be ionized by a weak signal from a broadcasting station through heavy broad electrical disturbances which cannot ionize the gas tube. However, if the broad electrical disturbances are heavy enough and occur at exactly the same time as the signal from a broadcasting station tending to ionize the gas tube, the broad disturbances may prevent the ionization of the gas tube by the sharp signal. But inasmuch as the common varieties of broad electrical disturbances are extremely brief in duration, the chance of their occurrence at exactly the right instant is small. It has been demonstrated that stop-on-carrier sets of the type shown in this application will consistently tune in weak broadcasting stations through extremely strong and frequent static disturbances.

In another aspect, it may be noted that stoppage of the tuning condensers will not be effected in response to a broad signal. It will, however, be effected by a narrow signal in the presence of a broad signal, if the former is of longer duration so that there is some time at which the control voltage resulting from the broad signal is low and that resulting from the narrow signal is high. Again, stoppage will not be effected in response to a narrow signal in the presence of an uninterrupted broad signal of sufficient amplitude. However, since the peaks of most undesired signals, such as static, are of brief duration, the present arrangement utilizing opposing control voltages provides a very effective means for eliminating the effects of interference.

While it is preferable, in order to minimize stoppage in response to static, that the single peaked control voltage have a lower maximum value than the maxima of the double-peaked voltage, and that the depression between the maxima of the latter be narrower, at least at its lower end, with respect to frequency than the upper part of the former, as indicated in Fig. 2, these are not necessary.

In the event the tuning of the receiver is carried out in one direction only i. e., by varying the frequency in one direction, the voltage represented by only one of the two peaks of the double peaked curve would be effectively utilized as the tuning means would be stopped at the resonant frequency when approaching that frequency.

Another balanced bridge circuit embodying the principles of the present invention is illustrated in Fig. 4. This circuit may be used with the particular circuit arrangements of Fig. 1 by substituting the elements enclosed in dotted lines for similarly enclosed elements in the latter figure. The primary 76 and secondary 76' of transformer 77 are connected to the circuit as previously described. A first tank circuit, tuned to intermediate frequency, is constituted by the primary winding, an adjustable condenser 220, an inductance comprising two parts 222 and 223, condenser 224, and the condenser 78. Portion 222 is made of comparatively few turns that are adjustable to vary the mutual inductance therebetween and an inductance 226 forming part of the second tank circuit. This construction provides, in effect, a Vernier adjustment for the mutual inductance. A second tank circuit, also tuned to intermediate frequency, is constituted by the condenser 224, the inductance 226 coupled to inductance 222—223, and an adjustable condenser 228. The junction of condensers 224 and 228 is grounded and the junction of inductance 226 and condenser 228 is connected to the tube to be supplied with the output from the balanced bridge circuit through the condenser 84.

The two tank circuits are coupled inductively by reason of the coupling between the inductances 222—223 and 226 and capacitatively through condenser 224. The mutual inductive reactance of inductances 222—223 and 226 and the capacitative reactance of condenser 224 are so adjusted that they are equal at intermediate frequency and the voltages across inductance 226 and condenser 224 are brought into exact phase opposition by a resistance 230 and a very small adjustable condenser 232 connected across condenser 220 and inductance 222—223. Considered in another light, the electromagnetic and electrostatic couplings are balanced or neutralized, i. e., the inductive and capacitative reactive components are made to balance or neutralize. There remains, however, a resistive component of coupling which can be balanced or neutralized only by a resistive component supplied, in the arrangement of Fig. 6, by the resistor 230.

The arrangement, like that of the previously described circuit, is such that at intermediate frequency the voltage across condenser 224 is equal to and opposite the voltage across inductance 226. In other words, there is zero effective coupling between the two circuits and zero voltage across the condenser 228.

It may be well at this point to describe briefly how the balanced bridge circuits are adjusted. In the circuit of Fig. 1, the condensers 81 and 82 of the two tank circuits are first adjusted to tune these circuits to intermediate frequency. The mutual inductance between the primary coil 76 and the secondary coil 81' is then adjusted to bring the steep depression or valley between the two peaks close to a minimum voltage, which should be close to zero on an unmodulated signal at intermediate frequency. Condensers 81 and 82 may then be readjusted to insure that both tank circuits are tuned to the intermediate frequency. The mutual inductance may then again be adjusted, as described above, to bring the two peaks of the curve 104 in Fig. 2 to approximately the same height on each side of the intermediate frequency. The resistance 80 should be maintained with close enough tolerance to insure the reduction of voltage across the condenser 82 to near zero at resonance. If the values of the circuits are correct, the adjusting screw should be adjusted for zero coupling between coil 76 and coil 81'. However, if the circuit constants are slightly incorrect, a limited amount of compensation may be obtained by means of the adjustment of coil 81'.

The approximate values of the circuit constants for the circuit of Fig. 1, and for an intermediate frequency of 460 kc. are as follows:

Condenser 81	200 mmf.
Condenser 82	78 mmf.
Condenser 83	22 mmf.
Inductance 81'	1.2 mh.
Inductance 76	.7 mh.
Condenser 78	.1 mh.
Condenser 79	700 mmf.
Inductance 76'	22 mh.
Resistance 80	17 ohms

It should be understood that the capacities of the condensers will vary somewhat with the distributed capacities of the inductances and that the resistance of resistor 80 will vary considerably with the Q of the circuits, i. e., with the

resistances of the other elements of the circuits.

The balanced bridge circuit of Fig. 4 is adjusted by first adjusting condensers 220 and 228 to tune the two tank circuits to intermediate frequency. The mutual coupling between the Vernier inductance 222 and the inductance 226 is then adjusted to bring the two peaks on either side of the intermediate frequency to approximately the same height. The condenser 232 is then adjusted for correct phasing, which, when attained, will bring the bottom of the steep depression between the two peaks close to zero voltage. The above described adjustments are all relatively independent of one another, the capacity of condenser 232 being so small as to have a negligible effect on the tuning of the tank circuit.

The approximate values of the circuit constants for the balanced bridge circuit of Fig. 4, for an intermediate frequency of 460 kc., are as follows:

Condenser 220	180 $\mu\mu$f.
Condenser 228	224 $\mu\mu$f.
Inductance 76	.7 mh.
Inductance 76'	.35 mh.
Condenser 224	720 $\mu\mu$f.
Condenser 78	.1 μf.
Inductance 222–223	.123 mh.
Inductance 226	.7 mh.
Mutual inductance 222–223, 226	.156 mh.
Resistance 230	250,000 ohms

The balanced bridge circuits described above, while of proven merit, are intended merely to be illustrative of the principles of the invention and may be modified by those skilled in the art to meet the exigencies of the particular installation or use. The primary principle embodied in the circuits is the obtaining of a reduced output voltage at a desired frequency which can be reduced substantially to zero by coupled circuits characterized by capacitative and inductive reactances brought into proper phase opposition, and furthermore where the output voltage is sharply decreased at the desired frequency. While proper phase opposition has been described as being obtained by adding resistance to the circuit or a resistance and a capacity controlling the effective value of the resistance, it is possible to obtain the phase opposition by utilizing a reactance element having a resistance component. Other modifications of the invention may be made without departing from the principles set forth herein.

What I claim as new, and desire to secure by Letters Patent of the United States, is:

1. In combination, a source of alternating current voltage, means including tuned means energized by said voltage for supplying a first control voltage which is substantially a maximum at a predetermined frequency, means including tuned means energized by said voltage for supplying a second control voltage opposing the first and which is a maximum at a frequency slightly displaced from said predetermined frequency and which drops sharply to a minimum at said frequency, said last mentioned means including also means coupled with said tuned means for reducing said minimum substantially nearer to zero than said minimum at said frequency, an electron tube having an output circuit, means responsive to changes in the current in said output circuit, and means for changing the current in the output circuit of said tube in response to said control voltages.

2. In combination, a source of alternating current voltage, means including tuned means energized by said voltage for supplying a first control voltage which is substantially a maximum at a predetermined frequency, tuned means comprising a pair of tuned circuits coupled through inductive and capacitive reactances to provide zero reactive coupling between the circuits at said frequency energized by said voltage, for supplying a second control voltage opposing the first and which is a maximum at a frequency slightly displaced from said predetermined frequency and which drops sharply to a minimum at said frequency, an electron tube having an output circuit, means responsive to changes in the current in said output circuit, and means for changing the current in the output circuit of said tube in response to said control voltages.

3. In combination, a source of alternating current voltage, means including tuned means energized by said voltage for supplying a first control voltage which is substantially a maximum at a predetermined frequency, means comprising a pair of tuned circuits coupled through inductive and capacitive reactances to provide zero reactive coupling between said circuits at said frequency energized by said voltage and means coupled with said tuned circuits having a resistance component adapted to effect more nearly opposite phase relationships between the voltage drops than resulting from the zero reactive coupling across said reactances for supplying a second control voltage opposing the first and which is a maximum at a frequency slightly displaced from said predetermined frequency and which drops sharply to a minimum at said frequency, an electron tube having an output circuit, means responsive to changes in the current in said output circuit, and means for changing the current in the output circuit of said tube in response to said control voltages.

4. In combination, a source of alternating current voltage, means including tuned means energized by said voltage for supplying a first control voltage which is substantially a maximum at a predetermined frequency, means energized by said voltage for supplying a second control voltage opposing the first and which has maxima at frequencies slightly displaced from said predetermined frequency and is a minimum at said frequency, said last mentioned means including a tuned circuit comprising a condenser and an inductance element connected to said voltage source and a second tuned circuit comprising said first condenser and a second inductance element coupled to the first, said first condenser and second inductance element being constructed and arranged so that the voltage thereacross is a minimum at said frequency, an electron tube having an output circuit, means responsive to changes in the current in said output circuit, and means for changing the current in the output circuit of said tube in response to said control voltages.

5. A combination as claimed in claim 4, wherein a second condenser is connected in series with the first mentioned inductance element and the second condenser and first inductance element are shunted by resistance means to effect more nearly direct phase opposition between the voltage drops occurring across said first condenser and second inductance element than resulting from said first condenser and second inductance element.

6. In a radio receiver of the type comprising tuning means, the combination including, means for driving the tuning means in opposite directions, and means for stopping said tuning means

when a broadcast station is closely tuned in, said last mentioned means including tuned means energized through the receiver for supplying a first control voltage which is a maximum when a station is closely tuned in, tuned means energized through the receiver for supplying a second control voltage opposing the first which is substantially zero when a station is tuned in and which has maxima exceeding the first control voltage when the station is not tuned in, and means controlled in response to said control voltages for controlling said driving means.

7. In a radio receiver of the type comprising tuning means, the combination including, means for driving the tuning means in opposite directions, and means for stopping said tuning means when a station is closely tuned in, said last mentioned means including a tuned circuit energized by the receiver for supplying a first control voltage which is a maximum when a station is closely tuned in, tuned means comprising a pair of tuned circuits coupled through opposed inductive and capacitive reactances and energized through the receiver for supplying a second control voltage opposing the first and which is a minimum when a station is tuned in, means including a normally deionized gas tube for controlling said stopping means, and means for controlling the ionization of said gas tube in response to said control voltages.

8. In a radio receiver of the type comprising tuning means, the combination including, means for driving the tuning means, and means for stopping said tuning means when a broadcast station is closely tuned in, said last mentioned means including tuned means energized through the receiver for supplying a first control voltage which is a maximum when a station is closely tuned in, tuned means energized through the receiver for supplying a second control voltage which falls sharply to a minimum when a station is tuned in, said last mentioned means including a tuned primary circuit and a tuned secondary circuit having an inductive and capacitative reactance common to both circuits providing zero reactive coupling at resonance, and means controlled in response to said control voltages for controlling said driving means.

9. In a radio receiver of the type comprising tuning means, the combination including, means for driving the tuning means, and means for stopping said tuning means when a broadcast station is closely tuned in, said last mentioned means including tuned means energized through the receiver for supplying a first control voltage which is a maximum when a station is closely tuned in, tuned means energized through the receiver for supplying a second control voltage which drops sharply to a minimum when a station is tuned in, said means including a tuned primary circuit and a tuned secondary circuit, an inductance in each circuit coupled together to provide a mutual inductance, a capacity common to both circuits in series with said mutual inductance to provide zero reactive coupling at resonance, and means controlled in response to said control voltages for controlling said driving means.

10. In combination, a source of alternating current voltage, means including tuned means energized by said voltage for supplying a first control voltage which is a maximum at a predetermined frequency, means energized by said voltage for supplying a second control voltage opposing the first and which has a maximum at a frequency slightly displaced from said predetermined frequency and is a minimum at said frequency, said last mentioned means including a tuned circuit comprising a condenser and an inductance element connected to said voltage source and a second tuned circuit comprising said first condenser and a second inductance element coupled to the first inductance element, said first condenser and second inductance element being constructed and arranged so that the voltage thereacross is a minimum at said frequency, means coupled with said tuned circuits for balancing out at least a portion of the resistive coupling between the two tuned circuits, an electron tube having an output circuit, means responsive to changes in the current in said output circuit, and means for changing the current in the output circuit of said tube in response to said control voltages.

11. In combination, a device to be operated, a source of alternating current voltage, means for supplying an actuating voltage which is sufficient to operate said device, means energized by said alternating current voltage comprising primary and secondary circuits tuned to a predetermined frequency and coupled inductively and capacitively and having substantially zero reactive coupling between them at said frequency for supplying a restraining voltage opposing said actuating voltage and which is a maximum at a frequency slightly displaced from said predetermined frequency and which falls to a minimum at said frequency, and means responsive to the difference between said actuating and restraining voltages for operating said device when said restraining voltage falls below said actuating voltage.

12. A combination as claimed in claim 11, wherein said primary and secondary circuits have coupled therewith resistive means for balancing out at least a portion of the resistive coupling.

13. In combination, a device to be operated, an alternating current amplifier associated with said device and passing a band of frequencies, and means including tuned means energized from said amplifier for supplying a voltage restraining operation of said device, said means being so constructed and arranged that the voltage falls to a value insufficient to restrain the operation of said device only over a band of frequencies substantially narrower than said amplifier frequency band and being a minimum at a predetermined frequency in said band of frequencies, said last mentioned means including also means separate from but coupled with said tuned means for reducing the effective resistance of said tuned means to narrow the frequency band over which the restraining voltage is lowered.

14. A combination as claimed in claim 11, wherein said primary and secondary circuits have coupled therewith means including resistive means for reducing the resistive component of the coupling and adjustable capacitative means for varying the effective value of said resistive means.

15. In frequency discriminating apparatus, the combination including, a device to be operated, means controlling the operation of said device, means for supplying said control means with an actuating voltage sufficient to operate said device at a predetermined frequency, a source of alternating current voltage and means coupled to said source for supplying a restrain-

ing voltage opposed to said actuating voltage having a minimum value at said predetermined frequency and effectively suppressing said actuating voltage except near said minimum value, said restraining voltage supplying means including frequency discriminating means having a voltage characteristic with a low minimum voltage at said predetermined frequency and with a maximum voltage at a frequency somewhat displaced from said predetermined frequency having a value many times the value of said low minimum voltage, said frequency discriminating means substantially attenuating the voltage supplied to it, and means amplifying the output of said discriminating means relative to said actuating voltage to provide a restraining voltage having a maximum voltage substantially higher than the maximum of said actuating voltage with little suppression of said actuating voltage at said predetermined frequency.

16. In a stop-on-signal radio receiver, a tuning control device to be operated, variable tuning means controlled by said device and amplifying means supplying an alternating current voltage of a limited band of frequencies, a coupling network having input terminals coupled to said amplifier and output terminals coupled to said device, said network including a plurality of coupling means having reactive and resistive coupling components coupling the input to the output, so constructed and arranged that the sum of the reactive coupling components is substantially zero at a predetermined frequency of said limited band of frequencies, and resistive means coupled with said coupling means for substantially reducing the sum of the resistive coupling components at said frequency.

17. In a stop-on-signal radio receiver, a tuning control device to be operated, variable tuning means controlled by said device and amplifying means supplying an alternating current voltage of a limited band of frequencies, a coupling network having input terminals coupled to said amplifier and output terminals coupled to said device, said network including a plurality of coupling means having reactive and resistive coupling components coupling the input to the output, so constructed and arranged that the sum of the reactive coupling components is substantially zero at a predetermined frequency of said limited band of frequencies, resistive means cooperatively associated with said coupling means for substantially reducing the sum of the resistive coupling components at said frequency, adjustable reactive means cooperatively associated with the output end of said network for providing an output circuit resonant at least near said predetermined frequency, means for separately adjusting the reactive couplings of said coupling means, and means for separately adjusting said resistive means.

18. In frequency discriminating apparatus, the combination including, a device to be operated, means controlling the operation of said device to effect operation thereof at a predetermined frequency, means for supplying said control means with an actuating voltage of one polarity sufficient to operate said device at said predetermined frequency, and means for supplying a restraining voltage of opposite polarity having a minimum value at said predetermined frequency and effectively suppressing said actuating voltage except near said minimum value, said last mentioned means including frequency discriminating means comprising a network having opposed reactive coupling means arranged to provide substantially zero reactive coupling component at said predetermined frequency and including a resistive coupling component, and resistive means coupled with said opposed coupling means for substantially reducing said resistive coupling component at said predetermined frequency.

19. In combination, a source of alternating current voltage, means including tuned means energized by said voltage for supplying a first control voltage which is a maximum near a predetermined frequency, means energized by said voltage for supplying a second control voltage opposing the first and which has maxima at frequencies slightly displaced from said predetermined frequency and is a minimum at said frequency, said last mentioned means including a tuned circuit comprising first and second condensers energized from said voltage source, a second tuned circuit comprising said first condenser and an inductance element connected to said voltage source through a third condenser, said first condenser and inductance element being constructed and arranged so that the voltage thereacross is a minimum at said frequency, an electron tube having an output circuit, means responsive to changes in the current in said output circuit, and means for changing the current in the output circuit of said tube in response to said control voltages.

20. A combination as claimed in claim 19, wherein a resistor is placed between said first condenser and said voltage source to effect more nearly direct phase opposition between the voltage drops occurring across said first condenser and said inductance element than that resulting from said first condenser and inductance element without said resistor.

21. In a stop on signal radio apparatus, a tuning control device to be operated, variable tuning means controlled by said device and amplifying means supplying an alternating current voltage of a limited band of frequencies, a coupling network having an input circuit coupled to said amplifier and an output circuit coupled to said tuning control device and providing an output voltage with a voltage characteristic having two voltage peaks with a depression therebetween, said depression having at least one high steep side, said coupling network including two inductances coupled together and connected to each other at one end, a first capacity, one side of which connects to the junction of said inductances and the other side being common to said input and output circuits, a second capacity in series between a first of said inductances and the input circuit, resistive means shunted across said second capacity and the first inductance, and a third capacity shunted across said first capacity and the second of said inductances.

22. In stop-on-signal apparatus, variable tuning means, means for varying said tuning means, a device to be operated for terminating variation of said tuning means to tune in desired signals, band pass amplifying means energized by said desired signals and by broad band interference and supplying an amplified signal of certain band width and voltage, and tuning signal discriminating means coupling said amplifying means to said device including means supplying a voltage for operating said device not substantially less than said certain voltage, and means including means producing a voltage not substantially less than said operating voltage and over the frequency

range of said band pass amplifying means opposing said operating voltage and low effective resistance sharp cut-off filter means coupled to said operating voltage supplying means and narrowing said operating voltage to a minor fraction of said certain band width and inhibiting response to said interference, whereby said discriminating means supplies no effective voltage to said device in response to said interference but supplies a narrow high sharply cut off operating voltage in response to said desired signal.

23. In combination, a device to be operated, an alternating current amplifier, means coupled to said amplifier supplying an actuating voltage to said device having a value at a predetermined frequency sufficient to operate said device, low resistance sharp cutoff filter means coupled to said amplifier supplying a restraining voltage opposing said actuating voltage having a minimum value near zero at said predetermined frequency and a maximum value, at a frequency somewhat displaced from said predetermined frequency, many times the value of said minimum value, whereby there is little or no suppression of said actuating voltage at said predetermined frequency and the restraining voltage effectively suppresses the actuating voltage at frequencies somewhat displaced from said predetermined frequency and the device is operated only very near said predetermined frequency.

24. In combination, a device to be operated, an alternating current amplifier, means coupled to said amplifier supplying an actuating voltage to said device having a value at a predetermined frequency sufficient to operate said device, means coupled to said amplifier supplying a restraining voltage opposing said actuating voltage having a low minimum value at said predetermined frequency and a maximum value, at a frequency somewhat displaced from said predetermined frequency, many times the value of said minimum value, and means for amplifying said restraining voltage relative to said actuating voltage, whereby suppression of said actuating voltage at said predetermined frequency is reduced and the restraining voltage effectively suppresses the actuating voltage at frequencies somewhat displaced from said predetermined frequency and the device is operated only very near said predetermined frequency.

25. In a stop-on-signal radio apparatus, a tuning control device to be operated, variable tuning means controlled by said device and amplifying means supplying an alternating current voltage of a limited band of frequencies, a coupling network having an input circuit coupled to said amplifier and an output circuit coupled to said tuning control device and providing an output voltage with a voltage characteristic having two voltage peaks with a depression therebetween, said depression having at least one high steep side, said coupling network including a plurality of coupling means having reactive and resistive coupling components coupling the input to the output circuit so constructed and arranged that the sum of the reactive coupling components is substantially zero at a predetermined frequency of said limited band of frequencies and resistive means coupled with said coupling means for substantially reducing the sum of the resistive coupling components at said predetermined frequency, and said output circuit including capacitative and inductive means having values tuning the output circuit to said predetermined frequency to raise the height of said peaks.

26. In radio apparatus responsive only to a desired signal very close to a predetermined frequency, a device to be operated, an alternating current amplifier, means coupled to said amplifier for supplying a broad actuating voltage tending to operate said device throughout a relatively wide frequency band, means coupled to said amplifier including low resistance sharp cutoff filter means having a sharp steep sided cutoff characteristic supplying a restraining voltage opposing said actuating voltage and having a wide peak portion from which it falls steeply to a narrow low portion providing a voltage-frequency curve having at least one high steep side and means controlling said device in response to said opposed actuating and restraining voltages and effecting operation of said device only when said actuating voltage exceeds the restraining voltage by a predetermined amount, whereby operation is effected solely by the broad actuating voltage and high selectivity permitting operation only very close to a predetermined frequency is effected solely by the steep fall of said restraining voltage along the voltage-frequency curve from peak portion toward low portion.

27. In stop-on-signal radio apparatus, a tuning control device to be operated, variable tuning means controlled by said device, amplifying means supplying an alternating current voltage, and a coupling network coupling said amplifying means to said tuning control device having an input terminal, an output terminal and a terminal common to said input and output, a capacitative reactance connected to the input terminal, a capacitative reactance connected to the common terminal, an inductive reactance connected to the output terminal, means connecting the other ends of said three reactances together, a capacitative reactance connected from the input terminal to said inductive reactance, said reactances having values such that there is substantially zero reactive coupling between said input and said output terminals at a predetermined frequency, and a capacitor connected between said output terminal and said common terminal having a value such that said inductive reactance is resonated substantially at said predetermined frequency.

28. A coupling network having an input and output terminal and a terminal common to said input and output, a capacitative reactance connected to the input terminal, a capacitative reactance connected to the common terminal, an inductive reactance connected to the output terminal, means connecting the other ends of said three reactances together, a capacitative reactance connected from the input terminal to said inductive reactance, said reactances having values such that there is substantially zero reactive coupling between said input and said output terminals at a predetermined frequency, and resistive means between said inductive reactance and said input terminal for neutralizing at least part of the resistive coupling component of said inductive reactance.

29. A coupling network having an input and output terminal and a terminal common to said input and output, a capacitative reactance connected to the input terminal, a capacitative reactance connected to the common terminal, an inductive reactance connected to the output terminal, means connecting the other ends of said three reactances together, a capacitative reactance connected from the input terminal to said inductive reactance, said reactances having

values such that there is substantially zero reactive coupling between said input and said output terminals at a predetermined frequency, a capacitor connected between said output terminal and said common terminal having a value such that said inductive reactance is resonated substantially at said predetermined frequency, and resistive means between said inductive reactance and said input terminal for neutralizing at least part of the resistive coupling component of said inductive reactance.

30. Coupling apparatus, including an input circuit, an output circuit, and means coupling said input circuit to said output circuit including a single coil having a certain value of reactance and other reactance means in series with said coil and having a different value of reactance and input circuit connecting means between said coil and other reactance means for causing currents of different value to flow through said coil and other reactance means to produce equal and opposite voltage drops across said coil and other reactance means at a predetermined frequency thus neutralizing the coupling between said circuits at said predetermined frequency, and capacitative reactance means in said output circuit and effective with said coil to produce parallel resonance in said output circuit substantially at said predetermined frequency.

WILLIAM J. O'BRIEN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,096,874	Beers	Oct. 26, 1937
1,999,359	Hopkins	Apr. 30, 1935
1,999,609	Henning	Apr. 30, 1935
2,044,645	Stapleton et al.	June 16, 1936
2,063,295	Braden	Dec. 8, 1936
2,112,687	Barton	Mar. 29, 1938
2,231,806	Goldsborough	Feb. 11, 1941
1,897,252	Gardner	Feb. 14, 1933
2,262,218	Andrews	Nov. 11, 1941
2,353,180	Muller	July 11, 1944
2,052,730	Stoutenburgh	Sept. 1, 1936
2,065,610	Paris	Dec. 29, 1936
2,123,924	Artzt	July 19, 1938
2,138,891	Soller	Dec. 6, 1938
2,169,096	Greenberg	Aug. 8, 1939
2,113,263	Aceves	Apr. 5, 1938