

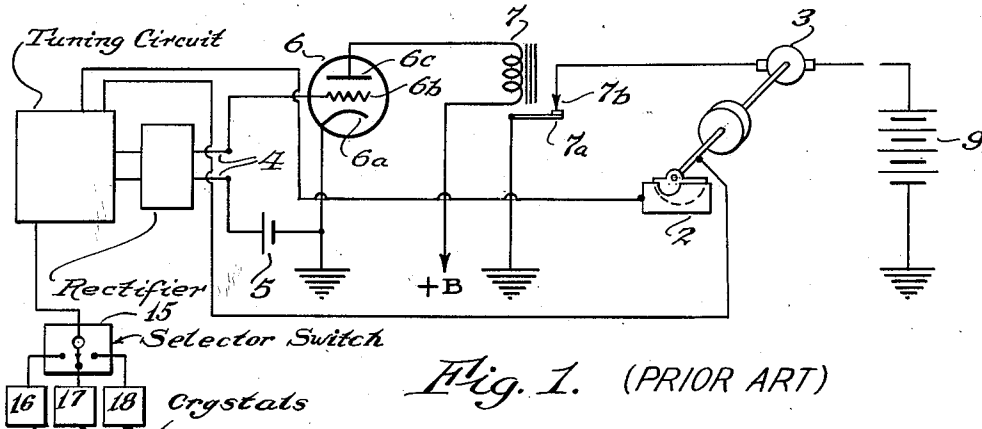
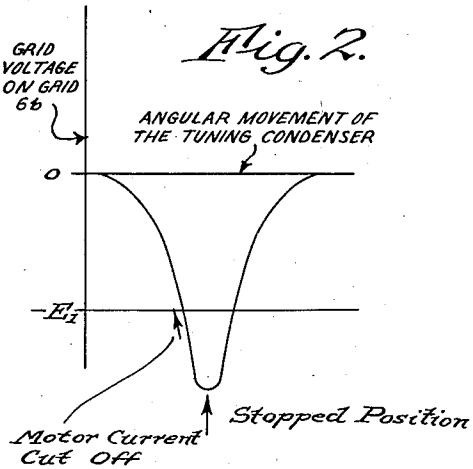
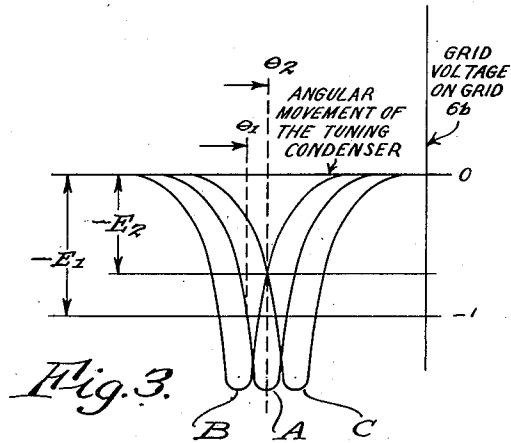
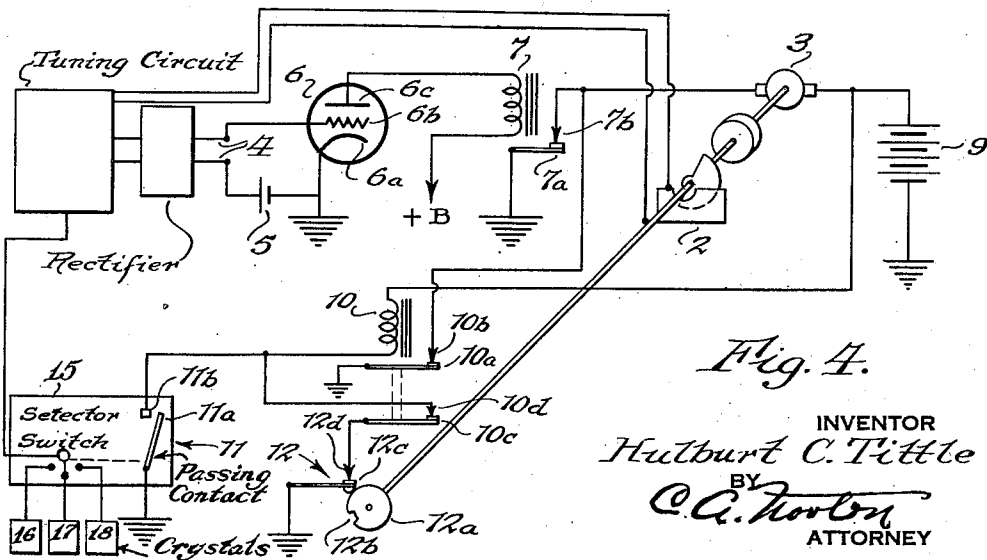
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H. C. TITTLE

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AUTOMATIC TUNING CONTROL CIRCUIT

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INVENTOR
Hutburt C. Tittle
BY
O. C. Horton
ATTORNEY

UNITED STATES PATENT OFFICE

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AUTOMATIC TUNING CONTROL CIRCUIT

Hulburt C. Tittle, Cheektowaga, N. Y., assignor
to Colonial Radio Corporation, Buffalo, N. Y.

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1

This invention relates to an automatic tuning control circuit, and more particularly to automatic crystal controlled radio transmitters or receivers, although it will be understood that my invention may be applied in other apparatus where automatic tuning of a circuit to any one of a series of predetermined frequencies is desired. Various forms of circuits of this type have been described and claimed in a co-pending application of William S. Winfield, Serial No. 463,775, filed October 29, 1942. In apparatus of this type, the circuits are automatically tuned to desired frequencies determined by crystals, and do not involve the setting of mechanical elements, such as pins, contactors, selecting cams, rocker bars, or the like.

In experimental work with apparatus such as that described in the above application, it has been found that, while the system described operates as contemplated when the resonance curves of the circuits controlled are separated or do not overlap to any considerable extent, difficulties may be encountered when the channels desired to be tuned are so close to each other that the resonance curves overlap to a considerable extent. Under such conditions the apparatus, when tuned to one frequency, may remain tuned to that frequency although the controls are operated to change the frequency.

It is an object of this invention to provide apparatus of the class described in which these difficulties are eliminated and reliability of operation is assured, even though a number of channels are provided so closely adjacent in frequency that the resonance curves of the apparatus for various channels overlap.

It is a further object of my invention to provide apparatus which will be closely tuned to the desired channel even though other channels are closely adjacent to the desired channel.

It is a still further object of my invention to provide improved apparatus of the class described having improved operational characteristics such that the apparatus will function and tune properly even where channels are as closely spaced as tuning selectivity permits.

Still other objects and advantages of my invention will be apparent from the specification.

In the drawing,

Fig. 1 is a circuit diagram of automatic tuning apparatus of the type to which my invention is applied.

Fig. 2 is a curve illustrating the operation of such apparatus.

Fig. 3 is a curve illustrating conditions when the

2

apparatus is required to tune to one of a number of closely spaced channels.

Fig. 4 is a circuit diagram of apparatus in accordance with my invention.

Referring now more particularly to Figs. 1 and 2, reference numeral 2 designates a variable tuning instrumentality such as a variable condenser, variometer, or the like, driven by a suitable operating means, such as motor 3, through a suitable reduction gearing, and serving to tune one or more controlling circuits, which may be oscillator circuits, antenna circuits, or, in fact, any tunable circuit required to be tuned and containing inductance (not shown), as well known in the art, with which tuning instrumentality 2 co-operates.

The tuning instrumentality, which, for sake of simplicity, is referred to as a condenser, although it may be another instrumentality, may be a single or gang condenser, and may tune one or more circuits, as may be desired, where two or more circuits are desired to be simultaneously tuned. The tuning instrumentality is arranged for continuous rotation; i. e., no stop is provided limiting its rotation to 180° as is sometimes used in condensers. For purposes of simplicity, the remainder of the tuning circuit or circuits is not shown, but a rectified voltage derived from the circuit by means of any suitable rectifier known in the art as in Figure 1 may be impressed through terminals 4 between the cathode 6a and control electrode 6b of a relay control tube 6.

Connected to the anode 6c there may be provided a relay 7, whose circuit may be completed to the +B source, the negative terminal of which is connected to cathode 6a. The relay winding 7 controls relay contacts 7a and 7b in such a manner that when plate current of a predetermined value flows through relay 7, contacts 7a and 7b are closed, thereby energizing the motor 3 through suitable power source 9.

A suitable source of biasing voltage 5 may be provided in the grid circuit of tube 6 if desired for the purpose of more exactly determining the operating characteristics of the tube 6.

The characteristics of tube 6 and its bias are so chosen that when the voltage impressed between terminals 4 is zero, the space current of tube 6 is more than enough to maintain contacts 7a and 7b closed. As the voltage across terminals 4 increases in such a direction as to make the grid more negative (E₁ Fig. 2) with respect to the cathode of tube 6, the plate current drops to such a value that the plate current of the tube 6 is insufficient to maintain relay contacts 7a and 7b in closed

position and those contacts open. For any value which maintains the grid more negative than this, the motor circuit will be open and the tuning instrumentality will remain in position.

If the grid 6b of tube 6 becomes less negative than this value, the plate current through tube 6 increases, relay 7 closes, the motor circuit is energized, and the tuning instrumentality is rotated, and this rotation will continue until a voltage sufficient to cause opening of the relay 7 is again impressed upon the tube 6.

In operation, assuming that the apparatus is arranged to control the tuning of a transmitter, the operator may have a channel selecting switch 15, by the operation of which he can connect into the tuned circuit a crystal such as crystals 16, 17, 18 for each frequency to be tuned. Assuming that the apparatus is tuned to a particular frequency as determined by crystal 16, for example and the operator operates the channel selecting switch 15 for a second channel having a different frequency, this disconnects the crystal 16 tuned to the first channel, which may be called channel A, and connects another crystal such as 17 tuned to the new channel, which may be channel B. Assuming that this channel is reasonably separated in frequency from channel A, the voltage generated in the tuned circuit associated with the crystal will drop to zero and, therefore, there will be no voltage impressed across the control circuit of tube 6.

The negative voltage impressed upon the tube 6 drops to a point where relay 7 closes and the motor is set into operation, varying the tuning of the circuit. The motor will continue to rotate, driving the tuning condenser until the tuning of the circuit begins to enter the resonance range of the new frequency selected, at which time the voltage impressed upon tube 6 will begin to rise in a negative direction, following the general form of the resonance curve as shown in Fig. 2, wherein ordinates represent grid voltage and abscissae angular movement of the tuning condenser.

Nothing occurs until the grid voltage reaches the magnitude $-E_1$, at which point the current in relay 7 has decreased sufficiently to permit contacts 7a and 7b to open. As will be understood, the motor will not instantaneously stop rotating, but will coast to a stop, the time required being dependent upon the inertia of the rotating system, the load upon it, and other factors.

Generally speaking, it will be found that some definite angular rotation occurs between the current cut-off point and the motor stopping point, which will be substantially constant for any given apparatus. This may be measured and is allowed for in selecting the point $-E_1$, in such a manner that motor current cut-off occurs just sufficiently in advance of the attainment of full resonance position by the tuning instrumentality, so that the coasting carries the circuit to the peak of the resonance curve and the stopped position of the apparatus is substantially as indicated in Fig. 2.

A somewhat more complicated condition is encountered when there are a plurality of channels so closely spaced that the resonance curves overlap. This condition may be represented in Fig. 3, in which A represents the resonance curve of the apparatus on channel A, B the resonance curve on channel B at a slightly lower frequency than that of channel A, and C the resonance curve of the apparatus on channel C, slightly higher in frequency than channel A. It will be observed that these resonance curves overlap, B overlapping A on one side, and C over-

lapping at the other, and both B and C overlapping A and each other at the center of A.

Here it should be noted that the voltage level $-E_1$ on Fig. 3 represents the grid bias which will cause the relay 7 to open the motor contacts. This may occur at an angular position of the condenser Θ_1 . The motor then coasts to a final position Θ_2 .

Although the relay opened at a voltage of $-E_1$ on curve A, a reduction of the negative bias voltage to this value will not be sufficient to cause the relay to close. It may merely cause chattering. To insure positive closure, the negative voltage must be reduced still further to a voltage level such as $-E_2$, which is just sufficient to cause the relay contacts to close. Generally speaking, the current in the relay actuating winding to produce closure is about twice that at which the relay will open; i. e., once closed, the relay will hold in closed position with about half the current required to move it from open to closed position. For the closing value, or any less negative value of grid voltage, the motor circuit will be closed. If resonance curves A and C overlap to such an extent that the negative bias developed, as indicated on resonance curve C, is greater than $-E_2$ in a negative sense, the motor circuit will not close when the operator moves the control switch from channel A to channel C, the tuning condenser will not be operated, and the circuit will remain tuned as if for channel A, which may be serious mistuning on channel C. The same would be true for any adjacent channels between A and C, for channel B, and for any channels between A and B.

I have found that this difficulty can be avoided by arranging the apparatus so that on the selection of a new channel, the motor circuit is positively energized and the relay 7 deprived of control of the motor until the motor has carried the tuning through the remaining channels available and started another excursion through the channels; that is to say, if the apparatus tunes over a frequency range of 500 to 1,600 kc., and happens to be tuned to 700 kc., then if the operator changes the frequency to 800 kc., the motor will begin to rotate and will tune the apparatus higher through 800 kc., and continue up to the end of the band, at which time the tuning condenser would continue to rotate until the tuning reentered by the lower end of the band; i. e., 500 kc. and began another cycle of tuning. This assures that a new channel must always be approached on the same angular side.

When the tuning instrumentality reenters the useful tuning arc (begins a new tuning cycle), control is restored to the relay 7 and normal operation is obtained. This is accomplished by the apparatus shown in Fig. 4, like that in Fig. 1, except in the following respects:

The apparatus shown in Fig. 4 has been provided with an additional relay 10 having an actuating winding connected in series with switch 11 having movable contact 11a and fixed contact 11b. This circuit is connected directly across the power source 9 so that whenever switch 11 is closed, current flows through the actuating winding of relay 10, thereby closing movable relay contacts 10a and 10c against the fixed relay contacts 10b and 10d respectively. It will be noted that contacts 10a and 10b keep the motor circuit closed independently of relay contacts 7a and 7b of relay 7.

In addition to relay 10, I may provide a cam switch 12 comprising cam disk 12a having a notch

12b adapted to receive the movable cam actuated contact 12c which engages fixed contact 12d. As shown, the cam switch 12 may be in series with relay contacts 10c and 10d and the branch of the circuit formed by these contacts and by the cam switch in parallel with the manual switch 11.

The cam disk 12 is geared or otherwise connected to the motor 3 in such a manner that the disk 12 makes one complete rotation while the tuning instrumentality is making one revolution. For example, each time the tuning condenser reaches such a position that the tuned circuit is at its lowest frequency and about to move its frequency upward through the tuning range, the cam notch 12b moves under the cam contact 12c and the latter falls into the notch and permits the cam switch to open.

With this combination of circuit elements it will be seen that when manual switch 11 is closed, a circuit is established through the actuating winding of relay 10, thereby closing relay contacts 10a and 10c against fixed contacts 10b and 10d. When this occurs, the relay 10 is locked in because the circuit in parallel to switch 11 is closed through the actuating winding through contacts 10c and 10d, and the cam switch 12. Manual switch 11 may now be opened without affecting subsequent operation.

It will also be seen that so long as relay 10 is energized the motor circuit will be closed through contacts 10a and 10b and, therefore, the motor will continue to operate as long as cam switch 12 is closed, regardless of the action of contacts 7a and 7b, in response to the plate current of tube 6, and the motor will continue to operate until the cam switch has rotated to a point corresponding to the beginning of the tuning cycle of condenser 2.

At this point cam switch 12 will open, interrupting the holding circuit of relay 10, and contacts 10a and 10b and 10c and 10d will open due to the interruption of current in the winding of relay 10. Control of the motor operation is now restored to the relay 7, and if the negative voltage impressed on terminals 4 is then sufficient to reduce the flow of plate current to the value of $-E_1$, the motor will be stopped just as if additional relay 10, manual switch 11, and cam switch 12 were not provided.

In short, the effect of the closure of manual switch 11 is to positively insure that no matter how many channels there may be to which the apparatus may be tuned, the tuning condenser will move through the uncompleted portion of the cycle in a positively locked condition where it cannot be stopped by the control voltage. When the uncompleted portion of the cycle is completed and the tuning condenser is ready to start another cycle, the lock-in circuit is opened by the operation of the cam switch.

In the foregoing description, it is assumed that the manual switch 11 is merely closed momentarily and is thereafter immediately opened. If the switch 11 were kept closed, the motor would continue to rotate indefinitely because the cam switch would not open the circuit of relay 10.

To provide against faulty operation in this respect, I prefer to provide switch 11 in the form of a passing contact on the channel selecting switch or switches in such a way that at any time the operator pushes a button for a new channel, switch 11 is momentarily closed to initiate the operation described, and is thereupon immediately opened.

In the specification I have explained the prin-

ciples of my invention and the best mode in which I have contemplated applying those principles so as to distinguish my invention from other inventions, and I have particularly pointed out and distinctly claimed the part, improvement, or combination which I claim as my invention or discovery.

While I have shown and described a preferred embodiment of my invention, it will be understood that modifications and changes may be made without departing from the spirit and scope of my invention, as will be apparent to those skilled in the art.

I claim:

1. In automatic tuning apparatus, in combination, a frequency determining element, a work circuit including a power source for delivering energy limited to a frequency determined by said element, said work circuit having a variable tuning instrumentality, power means for varying said tuning instrumentality, energy responsive means for interrupting operation of said power means in response to delivery by said work circuit of a predetermined level of energy, said last mentioned means being operatively associated with said work circuit and means for causing operation of said power means to move said tuning instrumentality through completion of one tuning cycle irrespective of the level of energy delivered by said work circuit.

2. In automatic tuning apparatus, in combination, a frequency determining element, a work circuit including a power source for delivering energy limited to a frequency determined by said element, said work circuit having a variable tuning instrumentality, power means for varying said tuning instrumentality, energy responsive means for interrupting operation of said power means in response to delivery by said work circuit of a predetermined level of energy, said last mentioned means being operatively associated with said work circuit means for causing operation of said power means, and means for rendering said energy responsive means inoperative through the completion of one tuning cycle, after the power means is set into operation.

3. In automatic tuning apparatus, in combination, a plurality of frequency determining elements, selecting means for selecting any one of said elements, a work circuit including a power source for delivering energy limited to a frequency determined by the selected element, said work circuit having a variable tuning instrumentality, power means for varying said tuning instrumentality, energy responsive means for interrupting operation of said power means in response to delivery by said work circuit of a predetermined level of energy, said last mentioned means being operatively associated with said work circuit means for causing operation of said power means to move said tuning instrumentality through completion of one tuning cycle irrespective of the level of energy delivered by said work circuit, and means for terminating the operation of said last mentioned means at a predetermined point in each tuning cycle.

4. In automatic tuning apparatus, in combination, a plurality of frequency determining elements, selecting means for selecting any one of said elements, a work circuit including a power source for delivering energy limited to a frequency determined by the selected element, said work circuit having a variable tuning instrumentality, power means for varying said instrumentality, resonance responsive means responsive to reso-

nance of said work circuit to said frequency-determining element for terminating operation of said power means, and means for rendering said last mentioned means inoperative until completion of the first tuning cycle after said power means begins operation.

5. In automatic tuning apparatus, in combination, a plurality of frequency determining elements, means for selecting any one of said elements, a work circuit including a power source for delivering energy limited to a frequency determined by the selected element, said work circuit having a variable tuning instrumentality, power means for varying said instrumentality, resonance responsive means responsive to resonance of said work circuit to said frequency-determining element for normally controlling operation of said power means, and means for depriving said resonance means of control over said power means during the completion of the first tuning cycle after said power means begins to operate.

6. In automatic tuning apparatus, in combination, a frequency determining element, a work circuit including a power source for delivering energy limited to a frequency determined by said element, said work circuit having a variable tuning instrumentality, power means for varying said tuning instrumentality, energy responsive means comprising a rectifier operatively associated with said work circuit, a resistance in circuit with said rectifier, a control tube, connections for impressing the voltage drop through said resistance upon the input circuit of said control tube, whereby the plate current of said tube is reduced in response to resonance in said work circuit, a relay operated by the space current of said control tube, said relay being interposed in circuit with said power means to control the operation thereof, a second circuit for energizing said power means exclusive of said relay, a second relay connected in said second circuit, and means for manually energizing said second relay, whereby said power means may remain energized independently of the action of the first said relay.

7. In automatic tuning apparatus, in combination, a frequency determining element, a work circuit including a power source for delivering energy limited to a frequency determined by said element, said work circuit having a variable tuning instrumentality, power means for varying said tuning instrumentality, energy responsive means comprising a rectifier operatively associated with said work circuit, a resistance in circuit with said rectifier, a control tube, connections for impressing the voltage drop through said resistance upon the input circuit of said control tube, whereby the plate current of said tube is reduced in response to resonance in said work circuit, a relay operated by the space current of said control tube, said relay being interposed in circuit with said power means to control the operation thereof, a second circuit for energizing said power means exclusive of said relay, a second relay connected in said second circuit, means for manually energizing said second relay, whereby said power means may remain energized independently of the action of the first said relay, and a cam operated switch synchronized with said tuning instrumentality for opening the energizing circuit of said second relay at a predetermined point in each tuning cycle.

8. In automatic tuning apparatus, in combina-

tion, a plurality of frequency determining elements, a selecting switch for selecting any one of said elements, a work circuit including power source for delivering energy limited to a frequency determined by the selected element, said work circuit having a variable tuning instrumentality, power means for varying said tuning instrumentality, energy responsive means comprising a rectifier operatively associated with said work circuit, a resistance in circuit with said rectifier, a control tube, connections for impressing the voltage drop through said resistance upon the input circuit of said control tube, whereby the plate current of said tube is reduced in response to resonance in said work circuit, a relay operated by the space current of said control tube, said relay being interposed in circuit with said power means to control the operation thereof, a second circuit for energizing said power means exclusive of said relay, a second relay connected in said circuit, means for manually energizing said second relay, and means comprising a passing contact operatively associated with said selecting switch.

9. In automatic tuning apparatus, in combination, a plurality of frequency determining elements, a selecting switch for selecting any one of said elements, a work circuit including power source for delivering energy limited to a frequency determined by the selected element, said work circuit having a variable tuning instrumentality, power means for varying said tuning instrumentality, energy responsive means comprising a rectifier operatively associated with said work circuit, a resistance in circuit with said rectifier, a control tube, connections for impressing the voltage drop through said resistance upon the input circuit of said control tube, whereby the plate current of said tube is reduced in response to resonance in said work circuit, a relay operated by the space current of said control tube, said relay being interposed in circuit with said power means to control the operation thereof, a second circuit for energizing said power means exclusive of said relay, a second relay connected in said circuit, and means for manually energizing said second relay, said means comprising a passing contact operatively associated with said selecting switch, and a cam operated switch synchronized with said tuning instrumentality for opening the energizing circuit of said second relay at a predetermined point in each tuning cycle.

HULBURT C. TITLE.

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