

Dec. 25, 1945.

R. W. MAY

2,391,470

AUTOMATIC TUNING APPARATUS

Filed May 17, 1943

4 Sheets-Sheet 1

Fig. 1.

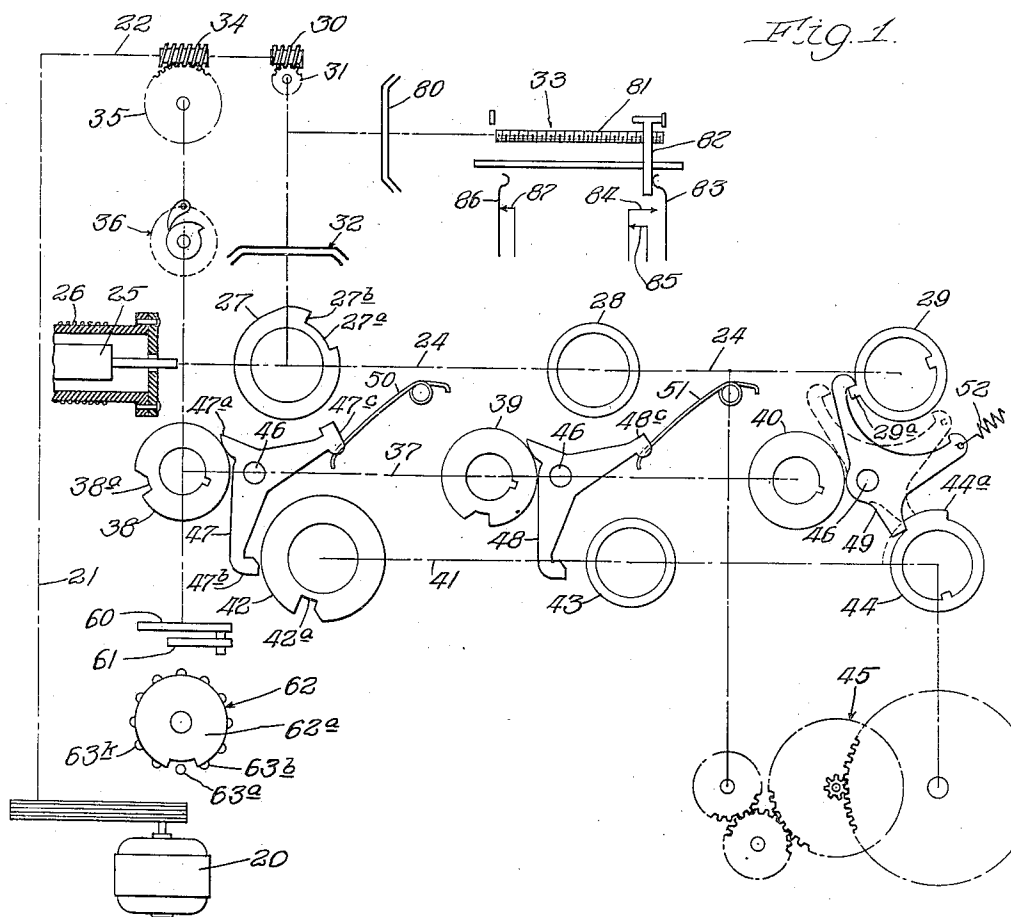


Fig. 2.

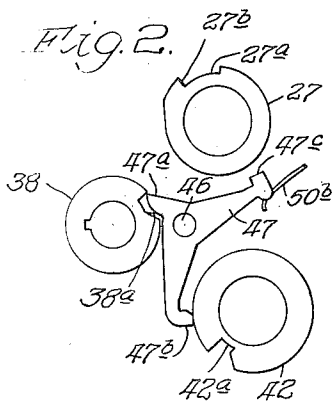


Fig. 3.

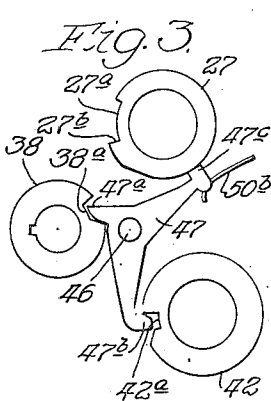
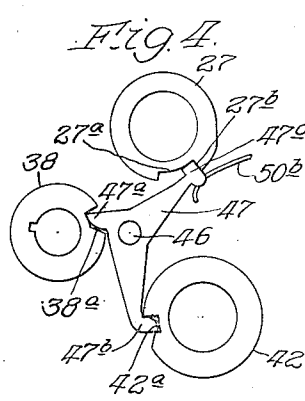


Fig. 4.



Inventor:
Richard W. May,
By *Clinton W. Wills, Davies,
Schroeder, Merriam, Feltz & Co.*

Dec. 25, 1945.

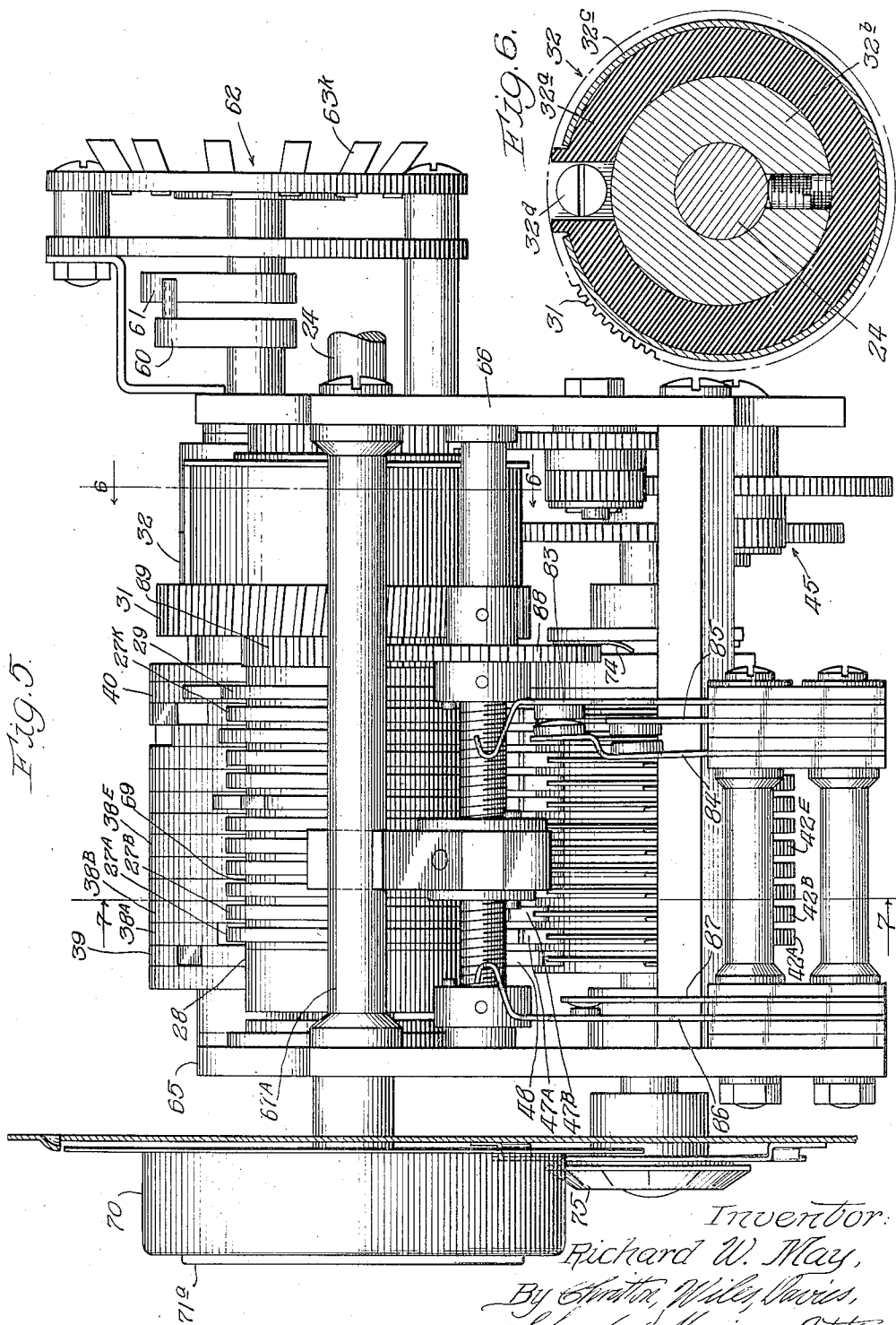
R. W. MAY

2,391,470

AUTOMATIC TUNING APPARATUS

Filed May 17, 1943

4 Sheets-Sheet 2



Inventor:
Richard W. May,
By *Charles Wiley Davis,*
Schneider, Merriam, & Co.,
Attorneys.

Dec. 25, 1945.

R. W. MAY

2,391,470

AUTOMATIC TUNING APPARATUS

Filed May 17, 1943

4 Sheets-Sheet 3

Fig. 7.

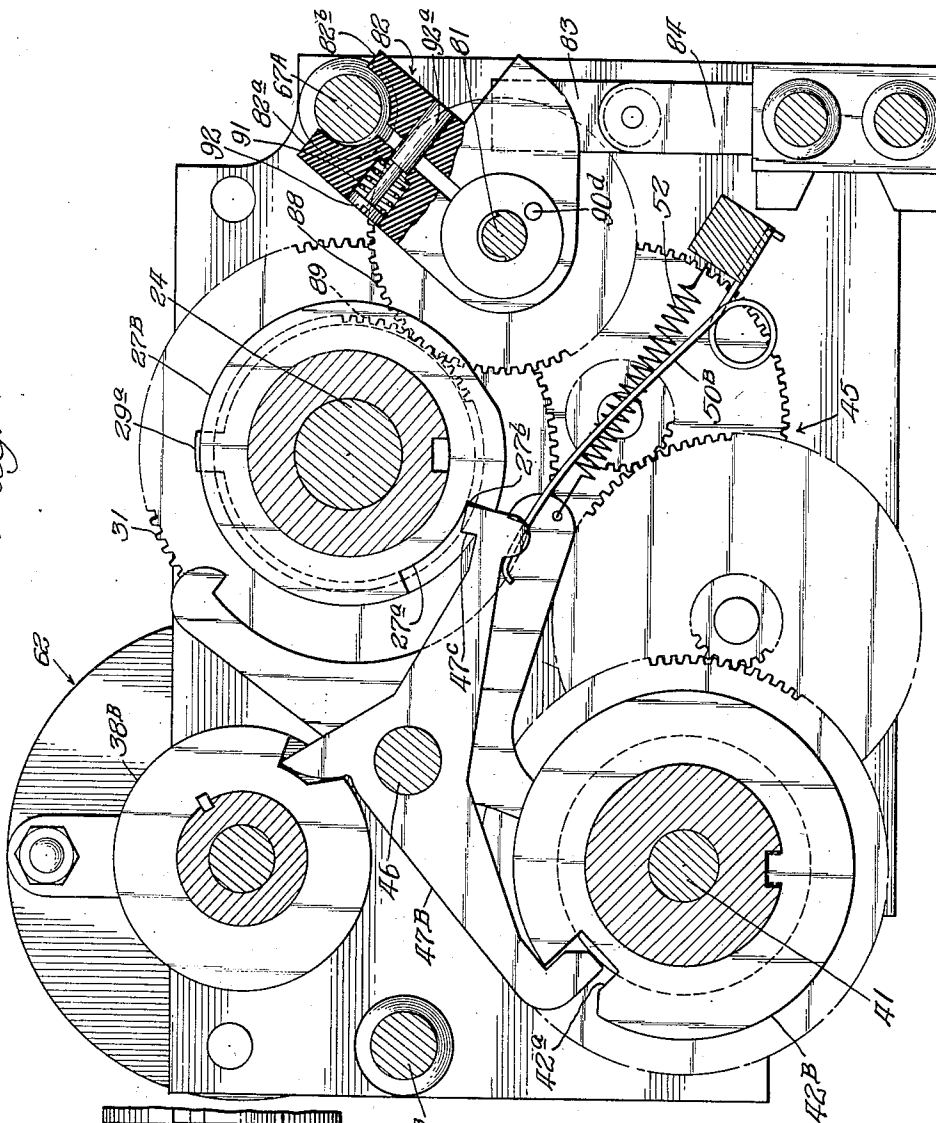
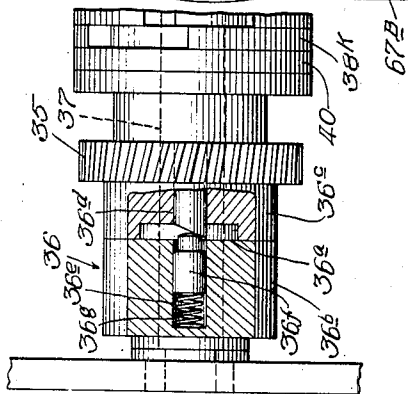


Fig. 8.



Inventor:
Richard W. May,
By *Arthur W. Davies*
Schroeder, Meniam, Fletting

UNITED STATES PATENT OFFICE

2,391,470

AUTOMATIC TUNING APPARATUS

Richard W. May, Cedar Rapids, Iowa, assignor to
Collins Radio Company, a corporation of Iowa

Application May 17, 1943, Serial No. 487,305

11 Claims. (Cl. 192—142)

This invention relates to automatic tuning apparatus for positioning a shaft at a desired point in any of a plurality of revolutions, and more particularly to a limit switch particularly designed for such tuning apparatus.

One feature of this invention is that it enables, without mechanical difficulties, proper electrical limit control of automatic tuning means for use with a radio tuning shaft rotatable through a plurality of revolutions; another feature of this invention is that rotation of the limit switch shaft may continue, after operation of the switch means, for as long as may be desirable without jamming of the operating parts; still another feature of this invention is that the actuating member for actuating the switch means is driven by a shaft rotatable through a large number of revolutions, preferably similar to the rotation of the tuned shaft; and yet another feature of this invention is that the actuating member is rotatably mounted on a nut on the limit switch threaded shaft with readily adjustable frictional engagement. Other features and advantages of this invention will be apparent from the following specification and the drawings, in which:

Figure 1 is a schematic diagram of apparatus embodying my invention, with the parts in one terminal position; Figure 2 is a schematic diagram of one portion of that shown in Figure 1, but in a different position; Figure 3 is a schematic diagram similar to Figure 2, but with the parts in still another position; Figure 4 is a schematic diagram similar to Figure 3, but with the parts in still a different position; Figure 5 is a side elevation of a shaft positioning unit adapted to automatically position a shaft at any desired point throughout a range of a plurality of revolutions, hereafter termed a "multi-turn" unit; Figure 6 is a transverse sectional view of the slip clutch, along the line 6—6 of Figure 5; Figure 7 is a sectional view of the multi-turn unit, along the line 7—7 of Figure 5, with a portion of the limit switch actuating member broken away; Figure 8 is an elevational view, partly in section, of the ratchet and one end of the selector cam assembly; Figure 9 is a fragmentary enlarged side elevational view of the limit switch, with the moving parts being shown in solid lines at one limit of their movement and in dotted lines at the other limit; Figure 10 is a view along the line 10—10 of Figure 9, partially broken away; and Figure 11 is a wiring diagram of a circuit adapted to operate the particular embodiment of my invention shown.

The multi-turn shaft positioning unit disclosed in this application is an improvement on auto-

matic tuning apparatus mechanically positioning the shaft of a tuned element automatically as the result of a sequence of operations initiated by movement of a control switch. Apparatus of this general type has been the subject of a number of patents issued to one Arthur A. Collins, one of the more recent of these patents being No. 2,285,414, issued June 9, 1942.

The automatic tuning arrangements which are the subject of such previous patents were all designed for and operable only in connection with a shaft designed to be rotated through an arc not exceeding one revolution, sufficient for the tuning of elements such as a conventional condenser, tap switch, or the like. Certain elements of a radio set, however, can be better tuned by a shaft rotatable through a plurality of revolutions. For example, a permeability tuning core is preferably moved in or out of its cooperating coil by rotation of a threaded lead screw which may rotate through twenty turns to vary the inductance from minimum to maximum; and certain types of condensers and carbon pile resistors are preferably driven by lead screws.

The said Arthur A. Collins has recently developed a multi-turn shaft positioning unit and associated operative mechanism and control circuit capable of rotating the shaft of a tuned element through any number of desired revolutions and of stopping the shaft automatically with a high degree of accuracy at any desired point in the entire range of movement. The general principles and major combination of elements of a multi-turn unit, and some of the detailed improvements thereof, have been invented by the said Arthur A. Collins and are the subject matter of his co-pending applications, Serial No. 472,717, filed January 18, 1943, and Serial No. 483,899, filed April 21, 1943. Certain other specific portions of a multi-turn unit have been improved by me. An improved limit switch specifically designed for such an automatic tuning device is the subject of this application; and certain other features are covered by my other co-pending applications, Serial No. 515,250, filed December 22, 1943, and Serial No. 487,728, filed May 20, 1943.

A radio receiver or transmitter embodying an automatic tuning arrangement of the kind disclosed here would be provided with one or more line shafts driven by a reversible motor, such shaft or shafts in turn driving through appropriate gearing one or more single-turn units of the kind disclosed in the previous mentioned Collins patents, or one or more multi-turn units of the kind disclosed in the Collins applications, or both,

these units positioning the shafts of a combination of tuning elements in positions appropriate to a given number of preselected frequencies. The operator of the radio set would then merely turn a switch or operate a telephone dial type of switch to select similar stop combinations in all of the units, whereupon the various circuit elements would be instantly and automatically tuned to the desired predetermined frequency. For simplicity of explanation only a multi-turn unit is shown here, but it will be understood that this can be used in combination with single turn units of the kind previously shown in issued patents or of the kind shown in the aforesaid Collins application, Serial No. 472,717.

In the particular embodiment of the invention illustrated here, and referring now more particularly to Figure 1, the schematic diagram, a reversible electric motor 20 drives a main shaft 21 which in turn drives a cross shaft or line shaft 22. This one line shaft may drive a number of separate tuning units simultaneously, or additional line shafts may be provided.

The main shaft of the multi-turn unit is the rotatable shaft 24 which operates through a lead screw arrangement to move a permeability core or tuning slug 25 axially of a coil 26, this core being so mounted (as by a splined arrangement not shown) as to enable axial movement while preventing rotational movement thereof. Mounted on a drum on the shaft 24 in a manner to be hereafter more fully described (normally non-rotatable with respect to the shaft) are a plurality of tuning stop rings 27, a manual stop ring 28 (which may be part of the stop means on the stop ring mounting drum), and a terminal stop ring 29. While all of these are non-rotatably locked to the shaft 24 during operation, the tuning stop rings 27 may be unlocked to permit setting or pre-selection of the point at which the shaft is to stop. A worm 30 on the line shaft 22 drives a worm gear 31 (as at a $12\frac{1}{2}$ to 1 ratio, for example), the worm gear driving one of the two elements of a slip-clutch 32, the other element of this clutch being connected to and driving the shaft 24.

The worm gear 31 also drives a limit switch, here indicated in general as 33, through a slip-clutch arrangement indicated as 30. A threaded shaft 81 carries an operating arm 82, this being shown in the terminal position of a cycle of operation, with the movable contact 83 out of engagement with the contact 84. Upon initiation of a cycle of operation by manipulation of the selector switch to call for a new frequency setting, the operating arm 82 travels to the left (83 first engaging 84 and moving it out of engagement with 85) until contact between 86 and 87 is broken, the motor thereafter reversing as will be more fully described later in connection with the circuit diagram (Figure 11), whereupon the limit switch arm reverses and travels back to its terminal position shown in Figure 1 of the drawings.

Another worm 34 on the line shaft 22 drives a worm gear 35 (as at a 40 to 1 ratio), this in turn acting through a single-tooth ratchet, here indicated in general as 36, to drive (in one direction only) a shaft 37. This shaft has non-rotatably mounted thereon a plurality of tuning selector cams 38, a manual selector cam 39, and a terminal stop ring 40 (which may be part of the cam drum). Another shaft 41 carries a plurality of secondary or turn determining cams 42, a secondary manual cam 43, and a terminal stop cam 44. This latter cam is immovably mounted on

the shaft 41, but the secondary cams are mounted with a frictional retention such that they normally move with the shaft, but can slip if the frictional force is exceeded. The shaft 41 is driven from the shaft 24 in fixed relation thereto by gearing, here indicated in general as 45, appropriate to the number of turns for which the unit is designed, as for example with a gear ratio of $23\frac{1}{3}$ to 1.

A stud 46 provides a mounting for a plurality of automatic tuning pawls 47, a manual tuning pawl 48, and a terminal stop pawl 49. The pawls 47 and 48 are biased in one direction by the rod springs 50 and 51, while the terminal stop pawl 49 is normally biased to a position intermediate the full line and dotted line positions by a coil spring 52.

Referring first to the terminal position pawl, all of the parts are shown at one terminal, where they would be if the manual tuning combination had been selected and a cycle of operation had been gone through with no automatic tuning. Upon operation of the control switch to call for automatic tuning to a pre-determined position, the shaft 24 and the ring 29 would begin counterclockwise rotation (speaking with respect to Figure 1), while the ring 44 would begin a corresponding clockwise rotation at a greatly reduced rate. As soon as this latter ring moved a few degrees the terminal stop pawl 49 would be permitted to assume an intermediate position under the influence of the spring 52, and the shaft 24 would be free to rotate through a desired number of revolutions (as a little over twenty revolutions) until the shoulder 44a had come around to its dotted line position and forced the terminal stop pawl 49 to its dotted line position, whereupon the shoulder 29a would engage one of the ends of this stop pawl and stop the tuned shaft at its other terminal position, hereafter designated the "home" position. Then as soon as the sequence of operations effected reversal of the motor 20 the shaft 24 and its associated rings would begin to rotate in the reverse or clockwise direction, being free to rotate in this direction until stopped by one of the tuning stop combinations or by the terminal stop arrangement as illustrated in solid lines.

When automatic tuning is effected by the sequence of operations to be hereafter more fully described, one step is the selection of the tuning pawl 47 which is to be rendered operative. This is accomplished by rotating the selector cam drum until the slot 38a lies immediately under the portion 47a of the pawl, the pawl then moving slightly (under the influence of the spring 50) until the end 47b drops down onto the periphery of the secondary cam 42, this position of the parts being shown in Figure 2. It is apparent that the pawl 47 is unable to move further until the slot 42a in the secondary or turn-determining cam 42 is opposite the end 47b (the parts 27 and 42 rotate after pawl selection has been made and the selector cam drum has stopped). When this registration does occur, as illustrated in Figure 3, the pawl moves further about its mounting stud 46, dropping down until its end 47c rests on the periphery of the stop ring 27. The stop ring then continues rotation (in a clockwise direction, speaking with respect to these views) until the end 47c of the pawl drops into the slot 27a and strikes what may be termed the forward shoulder 27b of this slot, this situation being illustrated in Figure 4. This stops rotation of the shaft 24 although, because of slippage in the

clutch 32, the line shafts and other units may continue until the cycle of operation is terminated.

It will thus be seen that a desired number of automatic stop combinations may be provided, each being a duplicate of the combination just described. Each such combination includes means for selecting that combination, one of the selector cams; means for determining in which turn or revolution of the shaft 24 the pawl will be permitted to move into operative relationship with the stop ring 27, this means comprising the secondary cam 42; and means for stopping the shaft of the tuned element at a desired point in the chosen revolution, this being effected by engagement of the end of the pawl with the forward shoulder of the slot of the stop ring 27. The shafts 24 and 41, and thus the stop rings and secondary cams, are maintained in synchronization and moved in appropriate ratios to each other by the interconnecting gear train 45, so that whenever a given stop combination is selected the shaft of the tuned element will be stopped very accurately and precisely at the chosen point in the chosen revolution, which point may be anywhere through a full range of continuous rotation of the shaft 24.

While the full sequence of operations of an automatic tuning cycle will be explained in detail later in connection with the description of the various switches and relays effecting such sequence, it is believed that understanding of the present invention will be facilitated by a brief description of a tuning operation at this time. When it is desired to change the transmitter to a different predetermined frequency the operator turns a control switch to the corresponding setting, whereupon the motor 20 starts to rotate in a direction moving all of the parts toward home position. The motor rotates through a predetermined number of turns determined by the limit switch, various tuned shafts reaching home position at various times (depending on their previous positions) and their respective clutches thereafter slipping. When this portion of the cycle is completed the motor continues operation in the same direction ("beyond home," as it might be termed) being stopped somewhere during this additional rotation by an automatic selector switch, stoppage of the motor occurring when the selector cam arrangements are in such position as to actuate the desired stop combination, the one corresponding to the control switch setting. Thereupon the motor reverses and drives the parts in the tuning direction (but without disturbing the selector cams), the various units rotating in this direction until each tuned shaft is stopped by the selected pawl at a position appropriate to the frequency desired, the respective clutches thereafter slipping until the motor and line shafts have completed the full cycle and have been stopped by the limit switch.

In order to effect selection of the desired stop combination the shaft 37 rotates, through a lost motion connection comprising the parts 60 and 61, the rotatable portion 62a of an automatic selector switch or circuit seeking switch 62. This switch comprises a plurality of fixed taps or contacts 63a—l and a rotatable member adapted to make contact with all of the taps except one which lies within the confines of a slot in this rotatable member. While the unit illustrated here is shown as having both a limit switch and a selector switch, in order that an operable unit

may be shown, it will be understood that only one of the units in a radio set need have these elements. All of the selector cam assemblies in the various units, however, must rotate in proper synchronization and registration with the selector switch 62, and this is accomplished by appropriate gearing and by the use of the single-tooth ratchets. It will be noted that there is no slip-clutch in the drive for the selector cam arrangement; and accordingly, the driving elements of the single-tooth ratchets 36 in all of the various tuning units rotate in fixed relation to each other. Since the ratchets are of the single-tooth variety this synchronization of the driving elements automatically results in synchronization of the driven elements, so that all of the various selector cam arrangements upon the initiation of each tuning cycle assume a synchronized relation with each other and then rotate together until they are stopped to make corresponding selections of stop combinations in all of the various tuning units. The lost motion connection comprising the parts 60 and 61 is used to enable the selector cams 38 to back off or shift position slightly as the portion 47a of the pawl drops into the selector cam slot. This movement of the selector cams must be permitted without movement of the selector switch 62, since any movement of the rotatable portion of this switch which would cause the edges of its slot to again contact the switch point 63a would cause undesired disturbance of the cycle of operations.

The provision of a manual selector cam 39 and cooperating pawl 48 prevent any accidental and undesired operation of one of the tuning stop combinations when it is desired to manually tune the shaft. When manual tuning is selected, movement of the portion 48a into the slot 39a locks the selector arrangement against rotation, so that vibration will not accidentally bring a tuning stop combination into operation. When the manual arrangement is actuated there is no hindrance to manual rotation of the shaft 24 as there is no projection on the outer end 48c of the manual pawl, and it cooperates with a smooth ring 28.

Referring now more particularly to the structural arrangement as illustrated in Figures 5-8, it will be seen that the parts are mounted in a self-contained unit between the plates 65 and 66 held in proper relation to each other by posts 67. A tuned shaft 24 carries an appropriate number (as 11) tuning stop rings 27A—K and the terminal stop ring 29, these being separated by spacer rings 69 keyed to a drum on the tuning shaft. Means is provided for selectively locking or unlocking the tuning stop rings 27 on the shaft 24 (not shown in detail here), this means being operated by the manually rotatable operating bar 71a in the dial 70. Unlocking is only for the purpose of setting the tuning stop rings to a desired position, and operatively they act as though they were at all times rigidly mounted on the shaft 24.

The secondary cams 42a—k are mounted on an appropriate drum on the shaft 41, with operating rings between them, the arrangement being similar to that of the stop rings except that the secondary cams are held in position by a spring 74 rather than by positive mechanical locking means. This spring provides sufficient tension to hold the secondary cams in fixed position for all operative purposes, yet enables them to be forceably moved or dragged around on the drum when a new tuning position is being set up. Since the

secondary cam shaft 41 is geared to the main shaft 24 any change in the setting of this latter effects a similar setting of whichever secondary cam is in engagement with a stop pawl at that time.

Referring now more particularly to Figure 6, it will be seen that the slip clutch 32 comprises as its two friction parts an annular shoe 32a of non-metallic material (as fiber or plastic) encircling a metal drum 32b fixedly mounted on the shaft 24. The annular shoe is held in place with the desired amount of frictional engagement by the encircling band spring 32c. The worm gear 31, rotatable about but not connected to the shaft 24, carries a stud 32d lying between the two end faces of the shoe 32a, the operation preferably providing a little clearance or lost motion. Rotation of the worm gear 31 by the worm 30 therefore transmits its force to the shaft 24 by pressure against one or the other of the end faces of the friction shoe 32a; and when the frictional grip of the shoe 32b is exceeded, the worm gear 31 can rotate without rotation of the shaft 34, slippage taking place between the shoe and the drum.

The details of the single-tooth ratchet are best seen in Figure 8. The driving element 36a is fixed to the worm gear 35, both being freely rotated about the shaft 37; while the driven member 36b is fixed to this shaft so that movement of the driven member effects movement of the selector cam shaft 37. The driving member 36a is provided with an annular slot 36c having a fixed pin 36d in one portion thereof, this pin having a sloping face. The cooperating driven member is provided with a bore or opening 36e in which a pin 36f is longitudinally movable against the force of a spring 36g, the bore registering with the annular slot. Rotation of the driving member in one direction (its direction of rotation during the tuning portion of the cycle) brings the sloping face into engagement with the movable pin and does not effect rotation of the driven shaft; rotation in the other direction (when the parts are being driven toward home position), however, causes driving engagement between the pins and rotation of the selector drum and cams.

Before describing the limit switch in detail the general operation of the device will be described, with particular reference to the circuit diagram, Figure 11. A battery 101 is illustrated as representative of any appropriate source of power for the motor and relays. The motor control relay 102 has an actuating coil 102a, three movable switch members 102b—d, three "upper" contacts 102e—g, and three "lower" contacts 102h—j. This motor control relay and the limit switch 33 cooperate to achieve the desired sequence of operations.

A manual selector switch, here identified in general as 103, is shown as having 12 switch taps a—l wired to the corresponding switch points 63 a—l of the automatic selector switch, the manual switch arm 103m being adapted to engage any one of the 12 switch points and thus to complete a circuit to any one of the corresponding automatic selector switch taps. The switch 104 is shown in a position enabling control by this manual selector switch; but when the switch 104 is thrown to its other contact a control switch of any desired type at some remote point may be operated. A relay 105 has cooperating contacts 105c and 105e which control the tuning circuit, and other contacts which may

control carrier emission or any other desired circuit, this and the manual switch 106 providing an interlocked action so that transmission is not effected while the automatic tuning device is operated.

Assuming that the parts are as shown in Figures 5-8, and it is desired to select another frequency setting, movement of the switch arm 103m might be made to the contact 103k, as shown in dotted line position. This movement completes a circuit from ground through disk 62a, contact 63k, wire 107, contact 103k, arm 103m, wire 108, switch 104, relay 105 (it being assumed that the carrier control switch 106 is open and the coil 105a not energized), wire 109, motor relay coil 102a, wire 110, battery 101 and wire 111 to ground. This energizes the motor control relay and causes its movable switch elements 102b—d to move from the positions shown to their lower positions. This energizes the motor 20 by a circuit including wire 110, contacts 102c and 102i, the motor armature, contacts 102b and 102h, and wire 111 back to the battery. This effects rotation of the motor in the home direction, the ratchet backing up the selector cam drum and lifting the pawls 47b out of the secondary cam and stop ring slots. At the same time the actuating member 82 of the limit switch 33 begins to travel downward and contact 83 makes engagement with the contact 84, breaking its contact with 85 and disabling the carrier control switch 106 until the tuning cycle is completed. The disk 62a of the automatic selector switch is also rotating during this operation but intermittent breaking of the contacts 63k has no effect because a holding circuit for the motor control relay has been energized through the limit switch contacts 86 and 87 and relay contacts 102d and 102j.

The motor continues operation until the tuned shaft has reached home position, the clutch thereafter slipping until the actuating member 82 of the limit switch opens the holding circuit contacts 86 and 87. This returns control to the automatic selector switch 62, and as soon as it reaches a position with its slot opposite the contact 63k the motor control relay circuit is deenergized and the motor reverses, leaving the selector cams in a position corresponding to the selector tap 63k, rendering a desired stop combination operable.

Return of the movable parts of the motor control relay to the position shown in the drawings completes another circuit to the motor in such a way as to cause its operation in a reverse direction, as mentioned, this circuit including wire 110, contacts 102c and 102f, wire 112, contacts 83 and 84, wire 113, contacts 102b and 102e, the motor armature, contacts 102d and 102g, and wire 111 back to the battery, it being noted that the upper end of the battery is now connected to the lower end of the armature, the reverse of the previous case. This causes movement of the various tuning device parts in the tuning direction, this continuing until the tuning shaft is stopped in its appropriate position by engagement of the chosen pawl with the forward shoulder of its cooperating stop ring slot (as illustrated in Figures 4 and 7), the clutch thereafter slipping to permit the motor drive to continue to terminal position. This terminal position is determined by opening of the limit switch contacts 83 and 84 by the actuating member 82. A bridging resistor 114 is associated with these contacts to always provide just enough current to keep the pawl in firm engagement with the shoulder of its cooperating stop

ring with a torque insufficient to overcome the resistance of the slip clutch.

As can be seen from the foregoing description, the limit switch 33 is a very important part of the apparatus. Moreover, in order to properly control a tuning shaft rotating through about twenty revolutions, the rotatable portion of the limit switch should have corresponding rotation. In order to enable this to be accomplished within reasonable limitation of space and with a good degree of accuracy the rotatable portion of the limit switch is made in the form of a threaded shaft member 81. As may be best seen in Figures 5 and 7, the shaft 81 is geared to the driving element of the clutch 32 by gears 88 and 89 of equal size (the gears 81 and 89 being rigidly fastened together), so that rotation of the shaft 81 always corresponds exactly to that of the line shaft.

As may be best seen in Figures 9 and 10, enlarged views, the shaft 81 has threaded thereon a nut 90 with a cylindrical bearing portion 90a on which the actuating member 82 is rotatably mounted for frictional engagement therewith, the parts being held in desired relation by the flanges 90b and 90c on the nut. As may be best seen in Figure 7, the actuating member 82 is centrally split, the two split portions 82a and 82b being urged together by the force of a spring 91, this being readily adjustable by rotation of the stud 82 threaded into a cooperating sleeve 92a in the portion 82b of the actuating member. The outer ends of the actuating member are provided with a semi-circular groove or depression embracing the post 67A to permit axial but prevent rotational movement of the actuating member.

The cycle of operations of the tuning device, particularly at the home end where the selector cams must be positioned, requires that the tuning shaft (and thus the threaded shaft 81 of the limit switch) rotate after the actuating member has reached its home terminal position (shown in dotted lines in Figure 9) and opened the contacts 86 and 87; and there is a certain amount of overrun at the other terminal position (shown in solid lines). In order to stop the actuating member, without jamming or sticking of the threaded shaft 81, I have provided the slip clutch arrangement between the nut 90 and the actuating member 82 as previously described, and means for positively rotating the nut within the actuating member.

In order to effect this rotation, collars 93 and 94 are rigidly mounted on the threaded shaft at each end thereof, the collar 93 having a projecting shoulder portion or stud 93a and the collar 94 having a similar projection shoulder portion or stud 94a. The nut is provided with cooperating shoulder portions on each side comprising the studs 90d and 90e. If the parts be assumed to be in the positions shown in solid lines in Figure 9, at the beginning of a tuning cycle, initiation of the tuning operation by movement of the manual switch arm 103m starts the threaded shaft 81 rotating in a counter-clockwise direction (speaking with respect to Figure 10) in exact correspondence with the rotation of the driving element of the clutch 32. Since the studs 94a and 90e are in the relation shown in Figure 10, the stud 94a can move away (counter-clockwise) with no frictional resistance of any kind to such movement; and the actuating member 82 starts to move along the shaft to the left (as shown in Figure 9), the frictional engagement between it and the nut preventing rotation between these two parts. As the actuating member moves to the left, its motion

effects a change in the relationship of the contacts 83, 84 and 85, as previously described; then moves through the desired period of drive motion (slightly more than twenty turns in the unit illustrated); and finally strikes contact 86 and opens its engagement with contact 87. Just after this has been done the moving parts reach the position shown in dotted lines in Figure 9 and stud 93a comes into contact with stud 90d, in a squared and non-wedging engagement of the same kind illustrated in Figure 10. This engagement causes rotation of the nut within the actuating member, this latter member slipping on the bearing surface 90a. Yet despite the force required to cause this slip-clutch action, the studs 93a and 90d are in such relation that when the motor reverses and the threaded shaft 81 starts to rotate in the opposite direction, the actuating member and nut may start to move back to their initial position with no frictional resistance or hindrance to the starting of such movement. That is, while the nut is positively rotated within the actuating member at each end of the travel of the latter, this positive rotating means does not wedge or jam in any way and the parts release instantly and move back in the other direction upon reversal of the motor within forces well within that provided by the slip-clutch frictional engagement.

While I have shown and described certain embodiments of my invention, it is to be understood that it is capable of many modifications. Changes, therefore, in the construction and arrangement may be made without departing from the spirit and scope of the invention as disclosed in the appended claims.

I claim:

1. In automatic tuning apparatus for positioning a rotatable shaft, including reversible drive means adapted to rotate the shaft through a plurality of revolutions, a slip clutch in the connection between the drive means and the shaft, a plurality of stopping means, each being adapted to stop the shaft at a predetermined point anywhere in its range of rotation, and selecting means for rendering operative a desired one of said stop means, this selecting means including a rotatable selector switch, a limit switch including: a threaded shaft member; switch means adjacent at least one end of the threaded member; a nut on said shaft; an actuating member rotatably mounted on said nut and having appreciable frictional engagement therewith, one of said members being adapted to be rotated by and in accordance with rotation of the drive means, movement of the actuating member along the threaded shaft being adapted to operate the switch means; and means for causing the nut to rotate with the threaded shaft at the desired limits of movement of the actuating member.
2. Apparatus of the character claimed in claim 1, wherein the last mentioned means includes shoulder means on the nut and cooperating shoulder means rigidly mounted on the threaded shaft.
3. Apparatus of the character claimed in claim 1, wherein the last mentioned means includes shoulder means on each side of the nut and cooperating shoulder means rigidly mounted on the threaded shaft at each end thereof.
4. In automatic tuning apparatus for positioning a rotatable shaft, including reversible drive means adapted to rotate the shaft through a plurality of revolutions, a slip clutch in the connection between the drive means and the shaft, a plurality of stopping means, each being adapted

to stop the shaft at a predetermined point anywhere in its range of rotation, and selecting means for rendering operative a desired one of said stop means, this selecting means including a rotatable selector switch, a limit switch including: a threaded shaft member adapted to be rotated by and in accordance with rotation of the drive means; switch means adjacent each end of the threaded shaft; a nut on said shaft; an actuating member rotatably mounted on said nut and having appreciable frictional engagement therewith; means preventing rotational but permitting axial movement of the actuating member, movement of the actuating member along the threaded shaft being adapted to operate the switch means; shoulder means on each side of the nut; and cooperating shoulder means rigidly mounted on the threaded shaft at each end thereof, whereby the nut is caused to rotate with the threaded shaft, but without jamming thereon, at the desired limits of movement of the actuating member.

5. Apparatus of the character claimed in claim 1, wherein the actuating member includes means for readily adjusting said frictional engagement.

6. Apparatus of the character claimed in claim 4, wherein the actuating member includes means for readily adjusting said frictional engagement.

7. Apparatus of the character claimed in claim 1, wherein the nut has annular flanges on each side thereof and the actuating member is rotatably mounted therebetween.

8. Apparatus of the character claimed in claim 4, wherein the switch means at one end of the shaft comprises a single pair of contacts and the switch means at the other end of the shaft provides two pair of oppositely operating contacts, one pair closing when the other opens and vice versa.

9. Apparatus of the character described for actuating a movable element, including: a

threaded shaft member; a nut on said shaft; an actuating member rotatably mounted on said nut and having appreciable frictional engagement therewith, one of said members being adapted to be rotated through a plurality of revolutions, movement of the actuating member along the threaded shaft being adapted to operate the movable element; shoulder means on the nut providing a shoulder surface parallel to the axis of the shaft; and cooperating shoulder means rigidly mounted on the threaded shaft providing a shoulder surface parallel to the axis of the shaft, whereby the nut is caused to rotate with the threaded shaft, but without jamming thereon, at the desired limits of movement of the actuating member.

10. Apparatus of the character described for actuating a limit switch, including: a threaded shaft member adapted to be rotated through a plurality of revolutions; a nut on said shaft; an actuating member rotatably mounted on said nut and having appreciable frictional engagement therewith; means preventing rotational but permitting axial movement of the actuating member, movement of the actuating member along the threaded shaft being adapted to operate the switch means; shoulder means on each side of the nut providing shoulder surfaces parallel to the axis of the shaft; and cooperating shoulder means rigidly mounted on the threaded shaft at each end thereof providing shoulder surfaces parallel to the axis of the shaft, whereby the nut is caused to rotate with the threaded shaft, but without jamming thereon, at the desired limits of movement of the actuating member.

11. Apparatus of the character claimed in claim 9, wherein the actuating member includes means for readily adjusting said frictional engagement.

RICHARD W. MAY.