June 17, 1947. S. Y. WHITE 2,422,381

METHOD OF LINING UP UNICONTROLLED TUNED RADIO APPARATUS

Original Filed Dec. 8, 1942 10 Sheets-Sheet 1

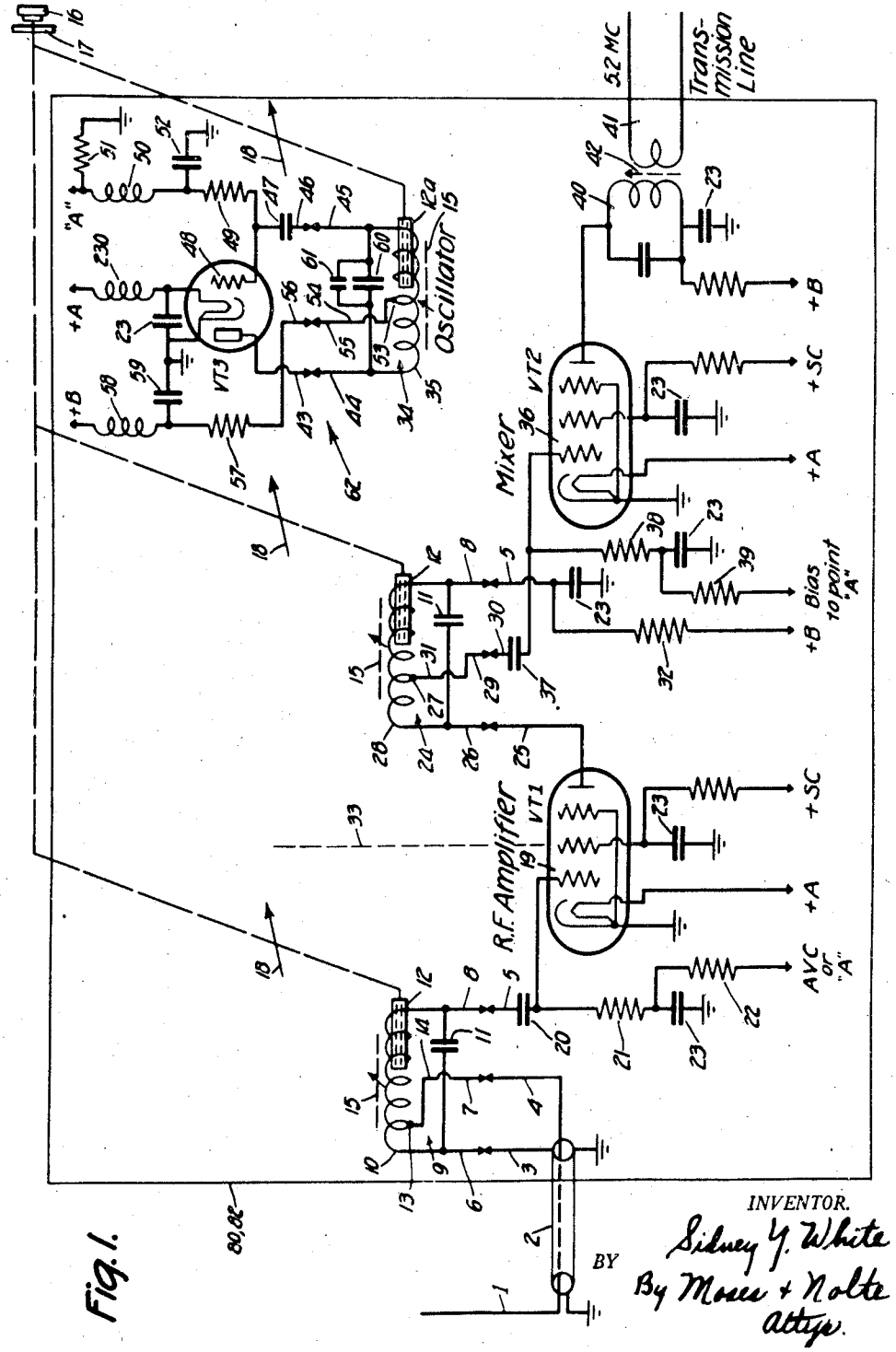

Fig. 1.

INVENTOR.
Sidney Y. White
BY
By Moses & Nolte
attys.

June 17, 1947. S. Y. WHITE 2,422,381

METHOD OF LINING UP UNICONTROLLED TUNED RADIO APPARATUS

Original Filed Dec. 8, 1942 10 Sheets-Sheet 2

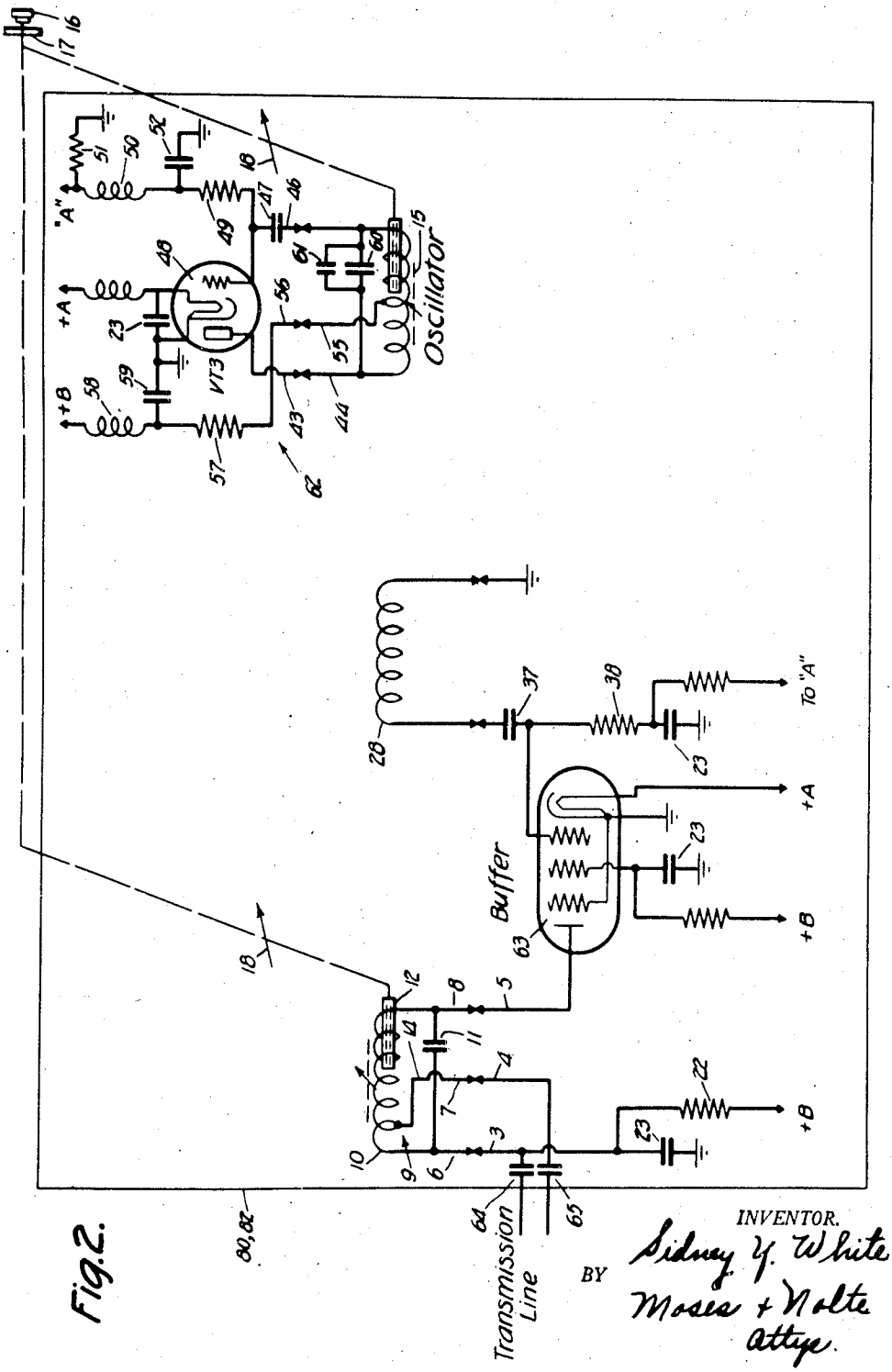

Fig. 2.

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June 17, 1947. S. Y. WHITE 2,422,381

METHOD OF LINING UP UNICONTROLLED TUNED RADIO APPARATUS

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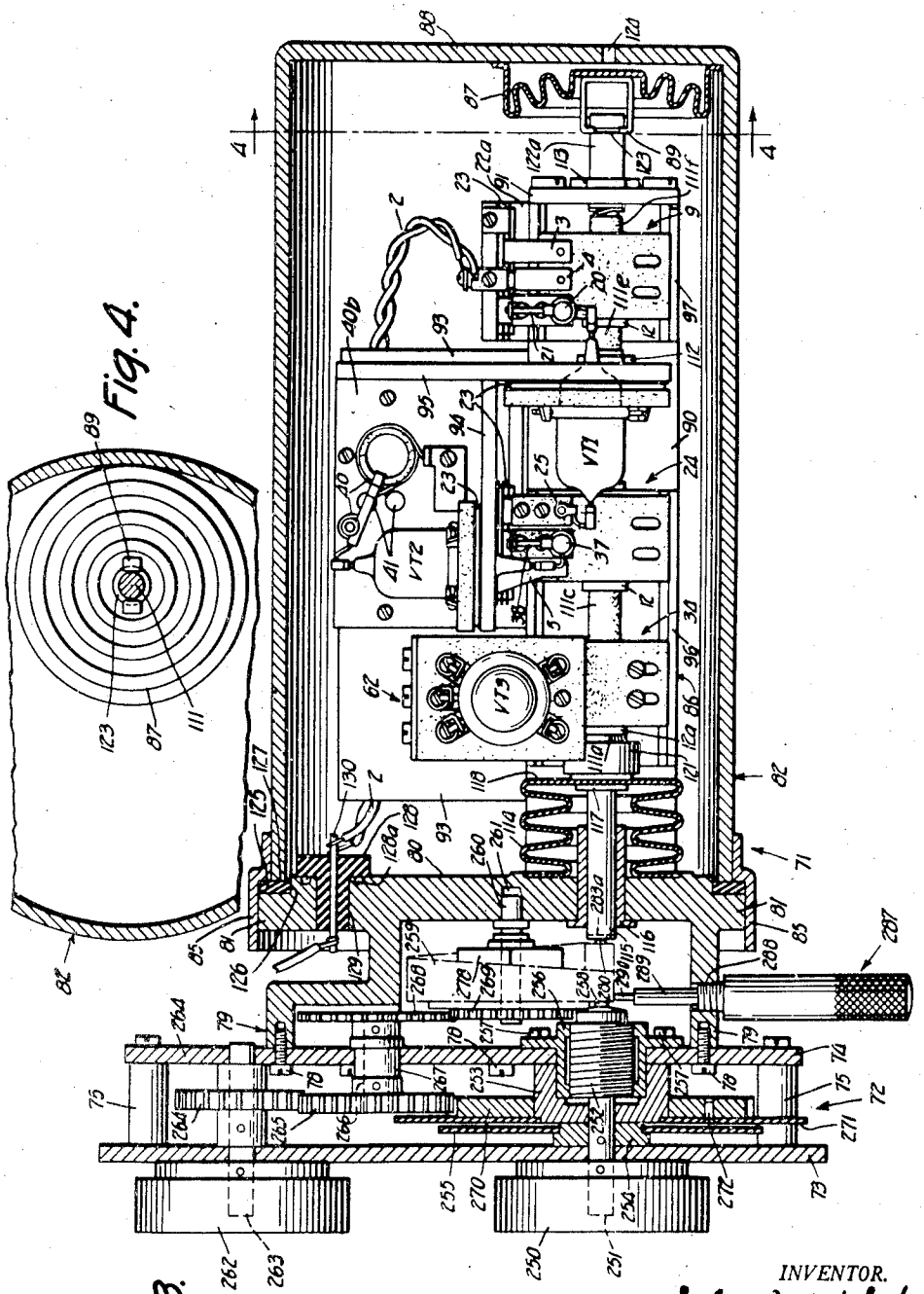

Fig. 3.

Fig. 4.

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Fig. 5.

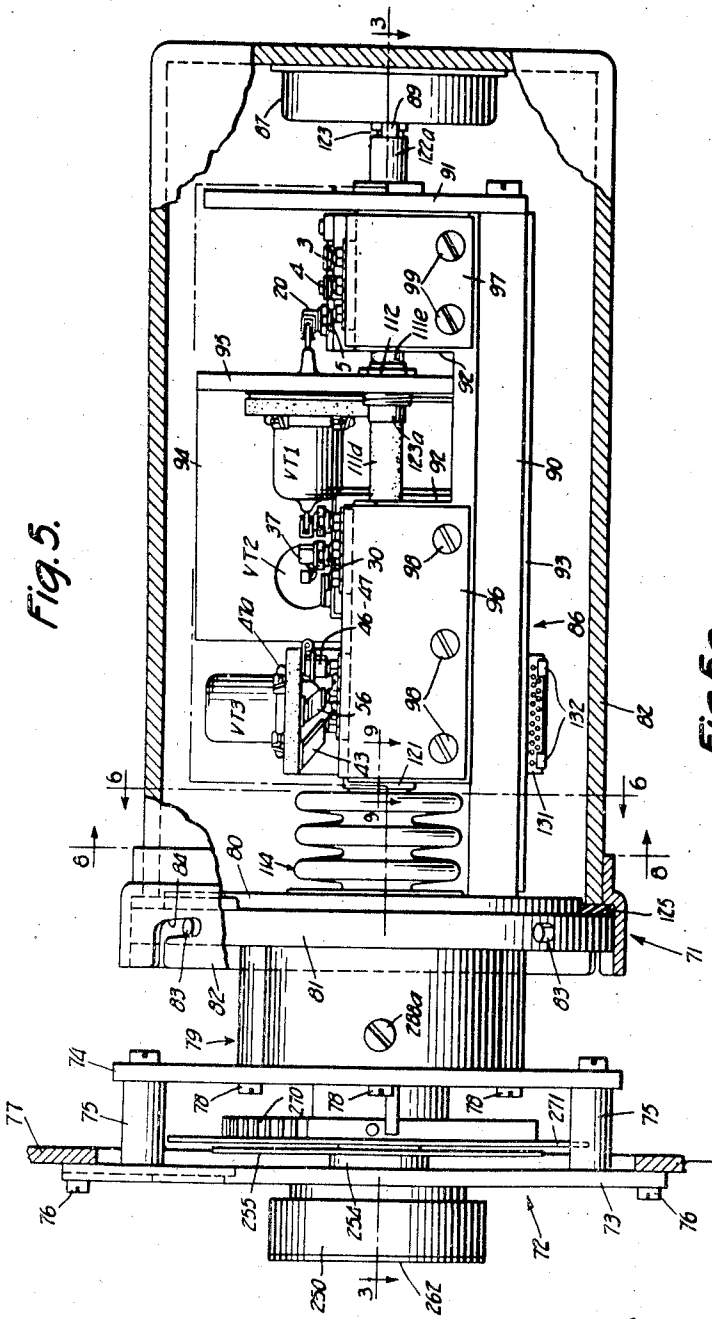
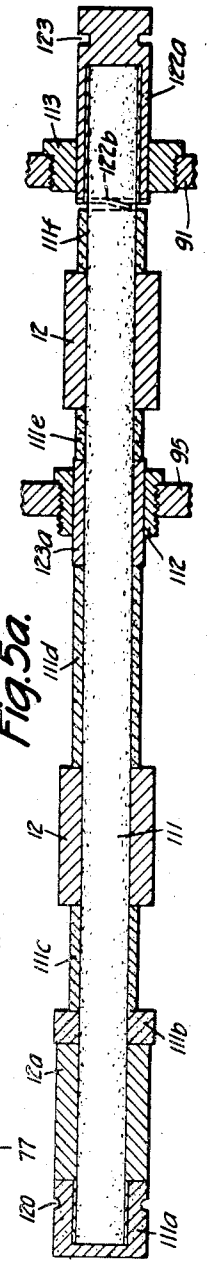


Fig. 5a.



INVENTOR.
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June 17, 1947. S. Y. WHITE 2,422,381

METHOD OF LINING UP UNICONTROLLED TUNED RADIO APPARATUS

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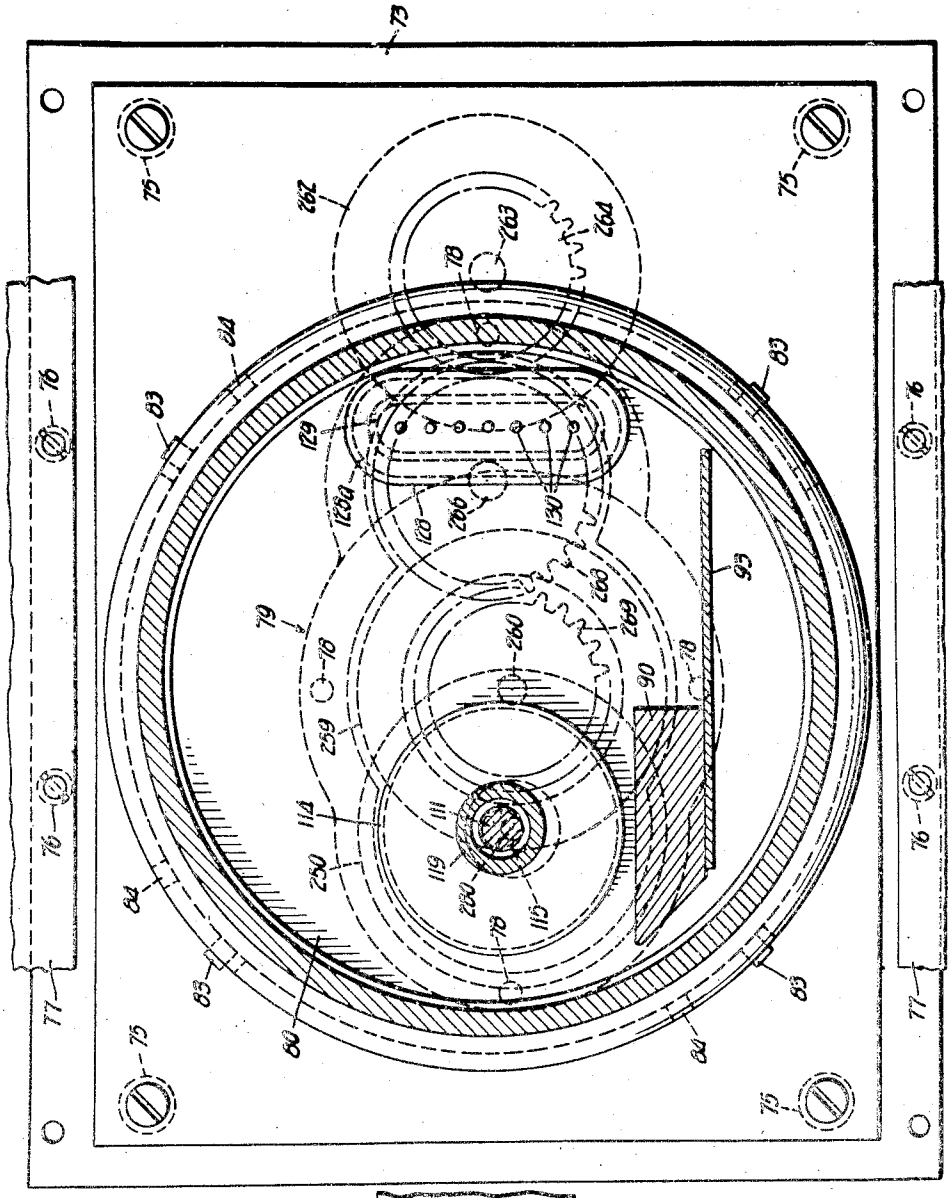

Fig. 6.

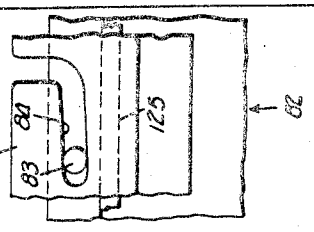

Fig. 7.

INVENTOR.
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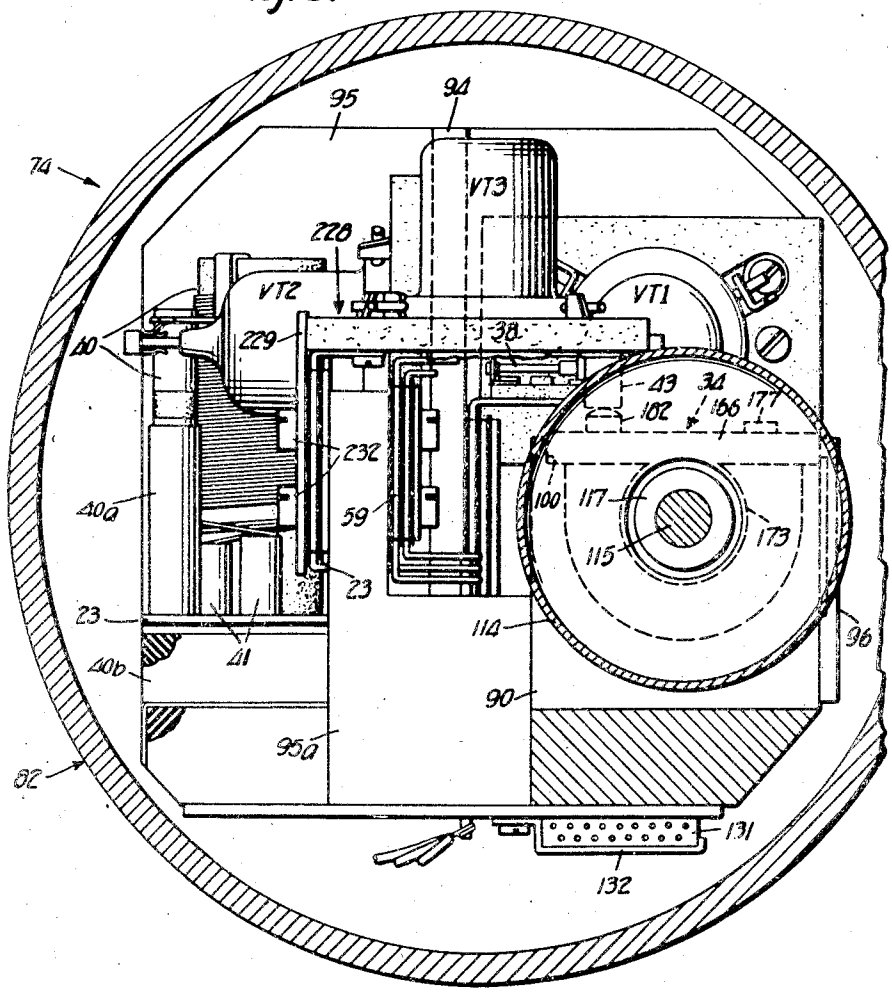
Fig. 8.



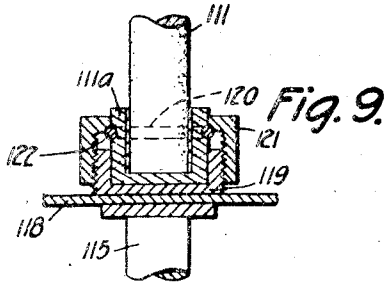


Fig. 9.

INVENTOR.
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BY Moses & Nolte
Attys.

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METHOD OF LINING UP UNICONTROLLED TUNED RADIO APPARATUS

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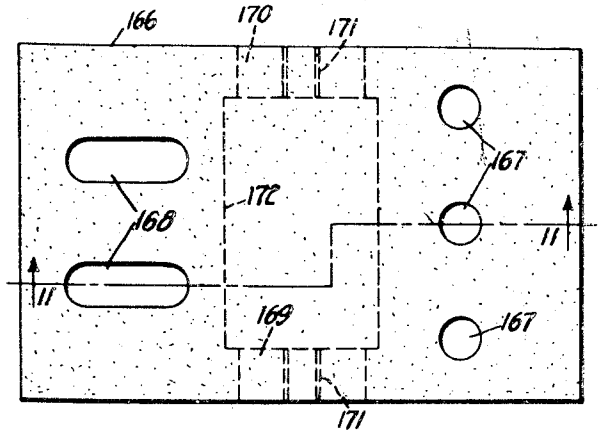


Fig. 10.

Fig. 11.

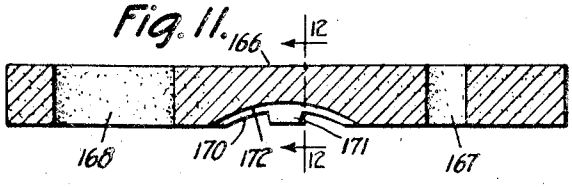
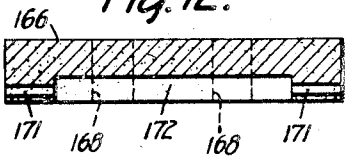


Fig. 12.



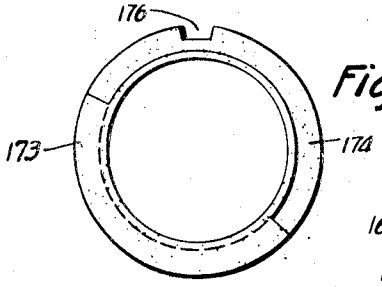


Fig. 13.

Fig. 15.

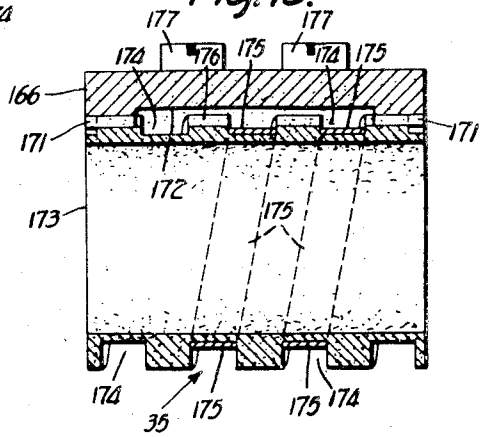
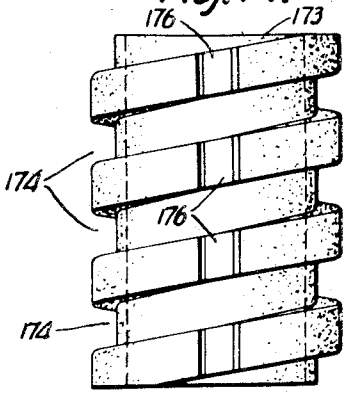


Fig. 14.



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June 17, 1947. S. Y. WHITE 2,422,381

METHOD OF LINING UP UNICONTROLLED TUNED RADIO APPARATUS

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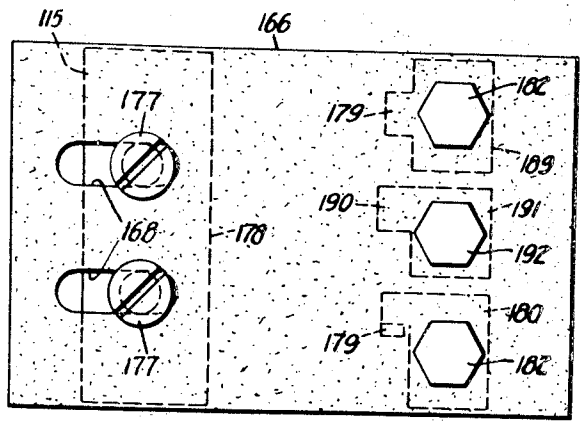

Fig. 16.

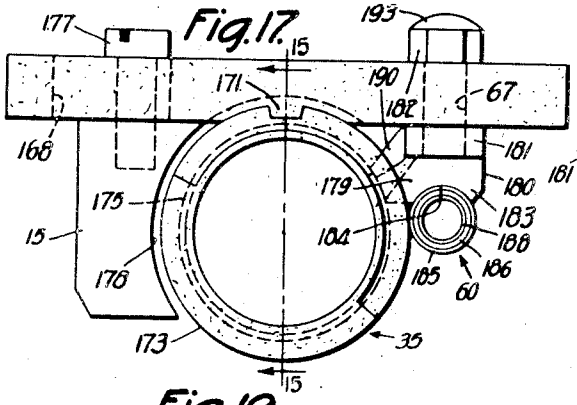

Fig. 17.

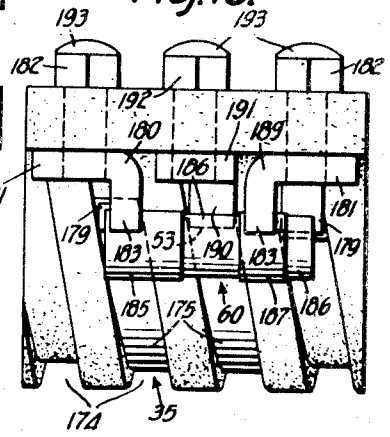

Fig. 18.

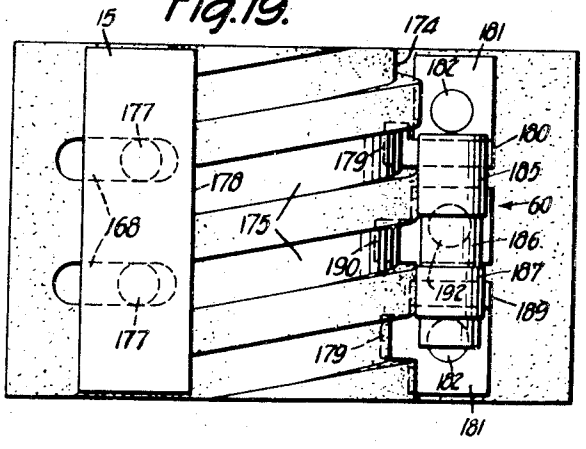

Fig. 19.

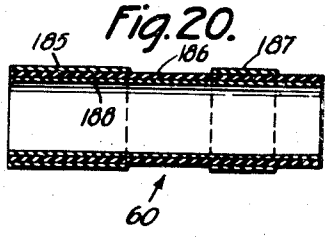

Fig. 20.

INVENTOR.

BY Sidney Y. White

Mouse & Nolte

Attys.

June 17, 1947. S. Y. WHITE 2,422,381

METHOD OF LINING UP UNICONTROLLED TUNED RADIO APPARATUS

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Fig. 23.

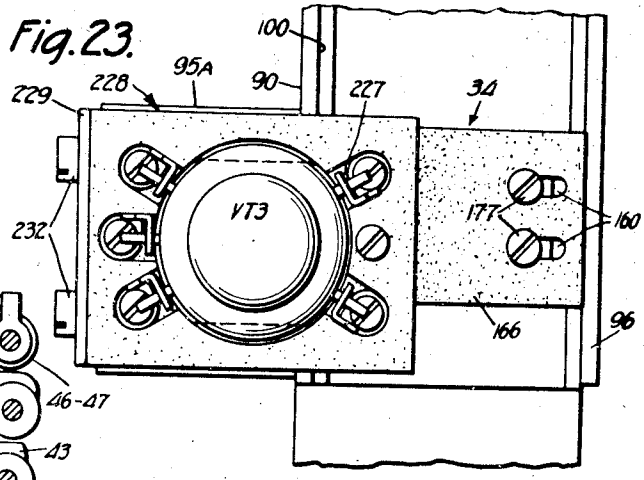


Fig. 24.

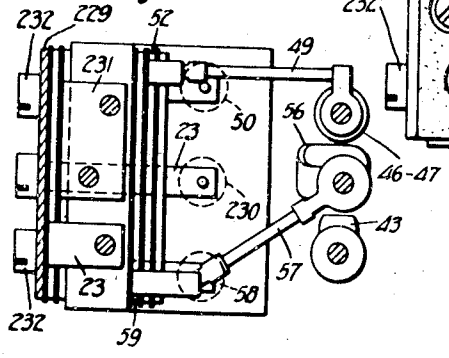


Fig. 22.

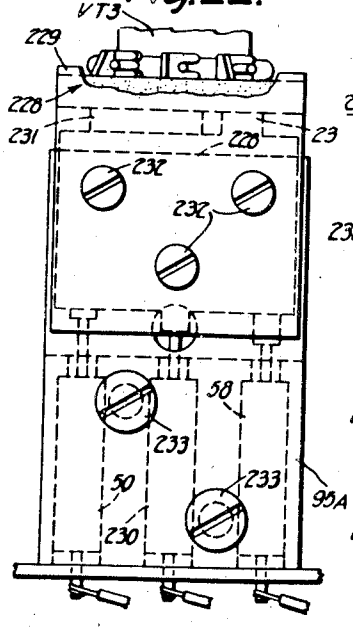
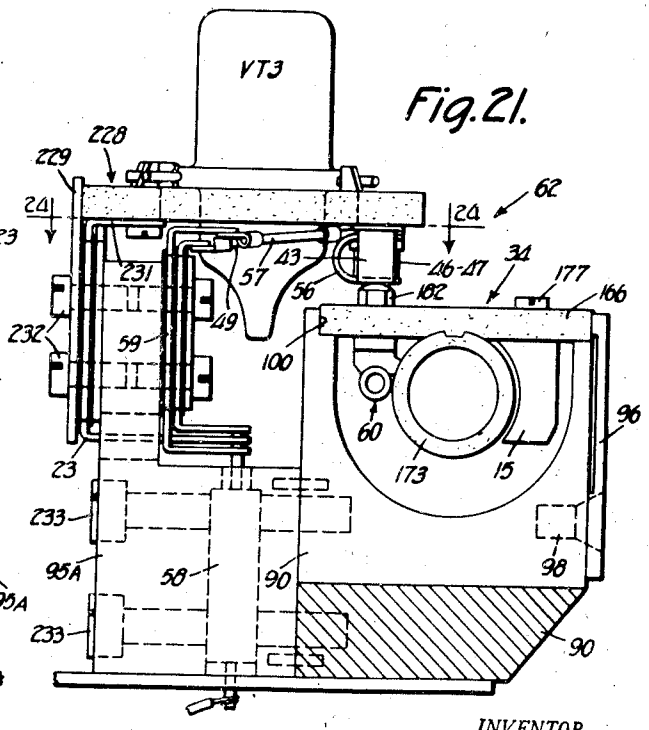


Fig. 21.



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June 17, 1947. S. Y. WHITE 2,422,381

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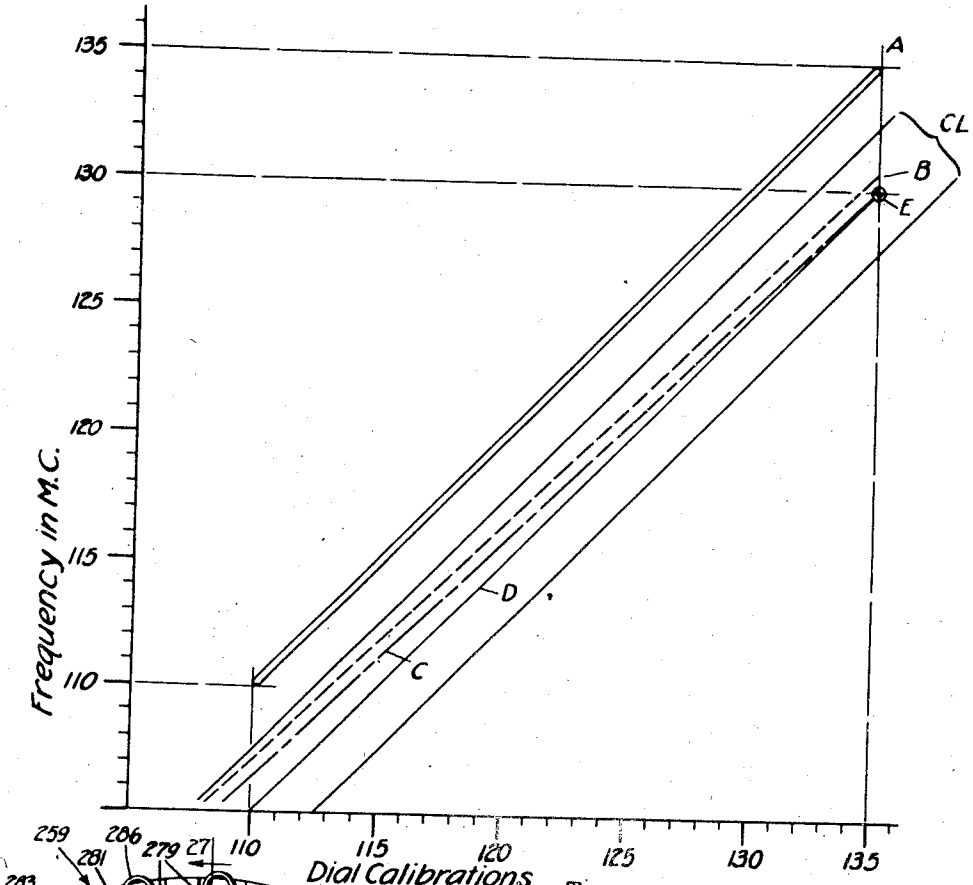
Fig.25.



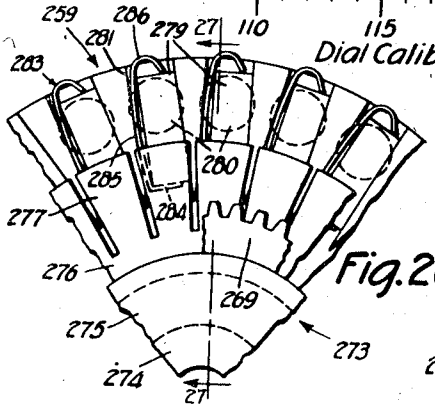


Fig.26.

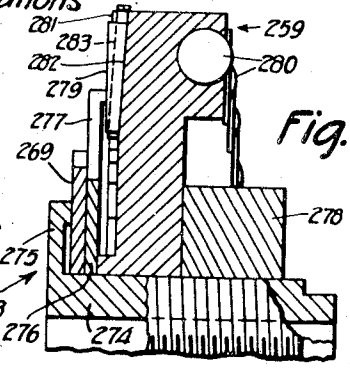


Fig.27

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Patented June 17, 1947 2,422,381

UNITED STATES PATENT OFFICE

2,422,381

METHOD OF LINING UP UNICONTROLLED TUNED RADIO APPARATUS

Sidney Y. White, Wilmette, Ill., assignor to Victor S. Johnson, Chicago, Ill.; Alex Thomson administrator of said Johnson, deceased

Original application December 8, 1942, Serial No. 468,195. Divided and this application October 15, 1943, Serial No. 506,375

2 Claims. (Cl. 250—20)

1

This invention relates to a method of lining up a unicontrolled core tuned radio apparatus having directly coupled oscillator and mixer circuits and an antenna circuit.

The present application is a division of my parent application Serial No. 468,195, filed December 8, 1942, for Precision radio apparatus. Features of said application disclosed but not claimed herein are claimed in said parent application and in other divisional applications thereof; to wit,

The complete disclosure of Serial No. 468,195 is made a part of the present specification by reference.

While the present invention is not limited to use in connection with the illustrative apparatus of Serial 468,195, its use in connection with such apparatus constitutes an important field of utility, and the invention will be disclosed herein in connection with certain forms of said apparatus.

In Serial No. 468,195, disclosure is made of mobile ultra high frequency radio apparatus suitable for meeting the exacting requirements of military service on land, at sea and in the air.

It is of the utmost importance that such apparatus be capable of preset dial tuning with an extremely high degree of accuracy, and that it be capable of sustained precision performance notwithstanding the fact that it is exposed to severe shocks and is subject to radical and abrupt changes of temperature, humidity and air pressure.

The crucial elements affecting the precision and the permanence of precision of receiver tuning and of transmitter tuning are found in, or in close association with, the ultra high frequency circuits. In accordance with Serial 458,195, these elements are chosen of such materials, are constructed in such form, and are associated and combined with one another into a head unit in such manner that the influence of temperature changes upon the frequencies is drastically and definitely limited, and that such slight changes of frequency with temperature as do occur are unalterable so that the initial limitation will be dependably maintained.

Tuning coils of the three circuits referred to are arranged in axial alignment, with the coil of the mixer circuit at a critical distance from the coil of the oscillator circuit. Tuning cores are provided for the respective coils, these cores being mounted in fixed relation to one another upon a member which is movable axially of the coils and which is operated to move the cores in unison by suitable dial mechanism.

In accordance with the present invention, the lining up of the circuits with one another and with the dial is accomplished by first connecting the mixer tube to act as a detector, then relatively adjusting the positions of the coil and core

2

of the mixer circuit and of the antenna circuit independently of the dial to line them up with a standard signal, locking them in the selected positions, reconnecting the mixer tube as a mixer and then relatively adjusting the position of the coil and core of the oscillator circuit independently of the dial to line up the oscillator with a standard signal.

After the circuits have been thus lined up with the signal, the cores are micrometrically adjusted relative to their associated coils and relative to the dial at a multiplicity of selected standard frequencies to establish a predetermined uniform relationship of the oscillator frequency with the dial readings of each of the selected frequencies.

Other objects and advantages will hereinafter appear.

In the drawing forming part of this specification

Fig. 1 is a diagrammatic view illustrating principally circuits employed in an illustrative receiver;

Fig. 2 is a view similar to Fig. 1 illustrating principally circuits employed in an illustrative transmitter;

Fig. 3 is a horizontal sectional view illustrating parts of the receiver unit;

Fig. 4 is a fragmentary sectional view taken upon the line 4—4 of Fig. 3 looking in the direction of the arrows;

Fig. 5 is a view in side elevation, partly broken away, of the structure illustrated in Fig. 3;

Fig. 5a is a fragmentary view showing the thrust rod and tuning core assembly;

Fig. 6 is a transverse vertical sectional view taken upon the line 6—6 of Fig. 5 looking in the direction of the arrows, the view being on a larger scale than Fig. 5;

Fig. 7 is a fragmentary detail view of the structure illustrated in Figs. 5 and 6;

Fig. 8 is a sectional view similar to Fig. 6 but taken on the line 8—8 of Fig. 5 looking in the direction of the arrows;

Fig. 9 is a fragmentary detail sectional view taken upon the line 9—9 of Fig. 5 looking in the direction of the arrows;

Fig. 10 is a top plan view of a coil and condenser supporting plate employed in the transmitter and in the receiver;

Fig. 11 is a sectional view of the supporting block shown in Fig. 10, taken on the line 11—11 of Fig. 10 looking in the direction of the arrows;

Fig. 12 is a sectional view of the block shown in Figs. 10 and 11 taken upon the line 12—12 of Fig. 11, looking in the direction of the arrows;

Fig. 13 is an end view of a coil form employed in both the transmitter and the receiver;

Fig. 14 is a plan view of the coil form shown in Fig. 13;

Fig. 15 is a longitudinal sectional view showing the plate of Figs. 10 to 12 and the coil form of Figs. 13 and 14 in assembled relation and with a coil wound on the latter, the section being taken on the line 15—15 of Fig. 17 looking in the direction of the arrows;

Fig. 16 is a plan view of the coil assembly of Fig. 15;

Fig. 17 is a rear end view showing the coil assembly of Figs. 15 and 16 together with an associated tank condenser;

Fig. 18 is a view in side elevation of the coil and condenser assembly of Fig. 17;

Fig. 19 is a bottom view of the coil and condenser assembly shown in Fig. 17;

Fig. 20 is a longitudinal sectional view showing details of the condenser of Figs. 17 to 19, inclusive;

Fig. 21 is an end view of the oscillator assembly cooperating with the tuned circuit assembly of Figs. 16 to 19;

Fig. 22 is a view in elevation of the structure shown in Fig. 21 as seen from the left of Fig. 21;

Fig. 23 is a fragmentary view looking down on the structure of Figs. 21 and 22;

Fig. 24 is a sectional view taken on the line 24—24 of Fig. 21, looking in the direction of the arrows, and with the tube of Fig. 21 removed;

Fig. 25 is a graph provided for use in explaining the alignment of the receiver and/or transmitter with the precalibrated dial;

Fig. 26 is a fragmentary detail view of mechanism employed in the train between the dial knobs and the tuning cores used after preliminary adjustments for securing and fixing the precise correspondence desired between the dial calibrations and the carrier frequency in megacycles at a multiplicity of predetermined points, as, for instance, every megacycle; and

Fig. 27 is a fragmentary sectional view taken upon the line 27—27 of Fig. 26 looking in the direction of the arrows.

An illustrative superheterodyne radio receiver for receiving radio waves of ultra-high frequency in connection with which the present invention may be advantageously employed, is illustrated in Fig. 1. In Fig. 1 reference numeral 1 designates the antenna, 2 designates a 36 ohm coaxial transmission line, the outer conductor of which is grounded and is connected to a switch contact 3, while the inner conductor of the line is connected to a switch contact 4. A third switch contact 5 is provided, the aforesaid switch contacts cooperating with switch contacts 6, 7 and 8 of a tuned circuit assembly 9. The assembly 9 comprises an inductance coil 10, whose ends are connected to switch contacts 6 and 8 and a fixed condenser 11, the tuning of the circuit to different carrier frequencies being effected by means of a movable core 12 which may be of the powdered iron type. An intermediate tap 13 on coil 10 is connected to switch contact 7 to provide a 36 ohm coupling point for the transmission line, the connection to switch contact 7 being designated by reference numeral 14. The slope of the tuning curve of circuit 9 is adjusted to a desired value by means of a movable slug 15 positioned alongside the coil 10, whose effect on the tuning of the circuit will be hereinafter described. The core 12 is adjusted by the operator to tune in the desired station by means of a unicontrol knob 16 associated with a precalibrated dial 17. In order that the resonant frequency of circuit 9 may be made to agree with the calibrations of dial 17, adjustable means as indicated by the arrow 18 is provided whereby the

relative position of the coil 10 and core 12 may be adjusted through a slight range independently of the dial setting. A full discussion of the manner of effecting the adjustments of elements 15 and 18 will be hereinafter described.

The voltage developed in circuit 9 is supplied to the control grid 19 of radio frequency amplifier tube VT1 through the condenser 20. Grid 19 is connected through the circuit shown, including resistors 21 and 22 and filter capacitor 23 to a source of A. V. C. voltage or source of bias potential such as the voltage source indicated at point A.

Capacitor 23 is of a type of construction found highly advantageous and desirable, and universally employed by me in the ultra-high frequency range, and consists of a sheet of metal separated from the body of the set by a sheet of mica, forming a non-inductive bypass to ground. This form of construction insures freedom from unwanted resonant circuit combinations formed by the wiring of the set and wherever a bypass condenser to ground is indicated in the drawing it is of this type. All leads have resistances in them, also to prevent formation of resonant loops. Resistance 22 is of the wire wound type being embedded in a grounded metallic block 22a (see Fig. 3) and acts as a radio frequency choke to prevent all radio frequency voltage from entering the supply leads.

The tube VT1 is supplied with the usual voltages for its electrodes and suitably bypassed. The plate of VT1 is connected to a resonant mixer circuit 24 through a pair of switch contacts 25—26. This circuit differs from circuit 9 mainly in the position of the tap 27 on the coil 28 of the circuit, this tap being connected to switch contact 29, which engages a switch contact 30 by means indicated by reference numeral 31, the construction of which will be hereinafter described in detail. The other connections of circuit 24 are similar to those of circuit 9 and are indicated by the same reference numerals. The tap 27 is provided to minimize grid circuit loading. Switch contact 5 is connected to a suitable source of B voltage through a resistor 32, and is also bypassed to ground as shown. The input and output circuits of VT1 are electrically shielded from each other by a grounded shield as diagrammatically indicated at 33 in Fig. 1, and physically illustrated as frame member 95 in Fig. 3.

Mixer circuit 24 is tuned to the signal frequency by means of a second core 12 and the adjusting means 18 and 15 for this circuit are similar to those described in connection with circuit 9. Voltage is injected into the resonant mixer circuit 24 from a resonant oscillator circuit 34 whose coil 35 is mounted coaxially with the coil 28, and at a critical distance therefrom. Voltage is supplied to the signal grid 36 of mixer tube VT2 through the circuit shown including a condenser 37, and bias is supplied thereto through the circuit shown including resistors 38—39, the latter resistor being connected to bias point A. Suitable voltages are supplied to the other elements of tube VT2 through the circuits shown, and the output of the tube is connected to a resonant circuit 40, which in the illustrated embodiment of the invention is tuned to a frequency of 5.2 megacycles. Resonant circuit 40 is coupled to a transmission line 41 through a transformer 42 or other suitable coupling means, as it has been found desirable in some cases to allow for a considerable physical separation of the whole tuning unit from its intermediate fre-

quency amplifier and power supply, and also from its antenna.

The oscillator circuit shown is of the "ultra-audion" type, which combines the advantages of requiring no feedback winding, as well as allowing grounding the heater and cathode. The fact that tuned circuit 34 is at high potential to ground is of little interest in core tuning, and grounding the cathode is of great practical advantage, as it has been found that the capacity from heater to cathode is effective in introducing circuit noises, which show up frequency fluctuations in the oscillator if it is attempted to run the cathode at some potential higher than ground. The plate of tube VT3 is connected to one end of coil 35 through a pair of switch contacts 43—44, and the other end thereof is connected to the grid of the tube through the switch contacts 45—46 and capacitor 47. The oscillator grid 48 has a divided grid leak consisting of resistor 49, choke 50 and resistor 51 to ground, and an isolation condenser 52. By suitable proportioning of resistor 49 and resistor 51 a negative voltage is built up at A suitable for supplying bias to the control grids of mixer tubes VT2 and/or vacuum tube VT1.

Tap 53 is brought out through switch contacts 55 and 56 by connector 54 and is energized through resistor 57 and choke 58 by a suitable source of B voltage. Isolation is effected by condenser 59 in the usual manner. Capacitor 60 performs the same function as 11 in tuned circuits 9 and 24, but it has been found desirable to also employ a condenser 61 for more complete thermal stability of the oscillator. The action of condenser 61 will be more fully discussed later herein.

The oscillator circuit 34 is tuned by means of a movable core 12*a* which is in turn operated through the adjustable connection 18 and control knob 16, thereby providing unicontrol tuning of the resonant circuit 9, mixer circuit 24 and oscillator circuit 34.

The oscillator 62 of Fig. 2 shows the same general structure used as a transmitter instead of a receiver. The entire oscillator assembly 62 is identical in every way with the oscillator assembly shown in Fig. 1. It is possible at times that this oscillator will be fed with somewhat higher plate voltage. Its components and performance will be otherwise identical. The R. F. amplifier shown in Fig. 1 is physically reversed so that its input and output circuits are interchanged, forming the buffer tube 63. Its input circuit may well be untuned and a coil 28 used to pick up some energy from the oscillator for exciting the grid through the condenser 37, its grid leak being 38 as shown. The tube is energized in the usual way and its output goes to tuned circuit assembly 9 through the contacts 5 and 8. Tuning condenser 11 resonates this combination whose frequency is controlled also by the core 12 physically connected to the dial through the adjustable means 18. The output transmission line is connected to the tuned circuit 9 through contacts 4 and 7, and plate voltage is applied to contacts 3 and 6 filtered by the condenser 23 and a resistor 22. Contact 3, being at ground potential to radio frequency by virtue of condenser 23, is connected to an output transmission line shown through condenser 64 and contact 4, likewise connected to the line by condenser 65, the purpose of condensers 64 and 65 being to remove D. C. potential from the line.

This assembly, therefore, forms a very low power continuous wave transmitter, but its main use is to energize either a final stage or a buffer meeting a final stage to provide reasonable power outputs.

As has already been indicated, the crucial and significant parts of the transmitter and of the receiver are those parts which control the frequency characteristics of the ultra-high frequency circuits of the structure, and those parts included in or closely associated with such circuits, which bear upon the precision of such control.

Important and significant elements, combinations and sub-combinations will be described and explained fully hereinafter. It is the present purpose to outline in a brief and general way the association with one another of the principal elements and assemblies and to describe the means for supporting and housing those elements in order that the place in the general scheme of the elements and combinations hereinafter described will be evident as the description proceeds.

The showing of Figs. 3 to 9, inclusive, is specifically of what may be termed the receiver head, but it is to be understood that the transmitter includes a similar head, differing from the receiver head only in such minor details as will be evident from the foregoing descriptions of the transmitter and receiver circuits.

The receiver comprises a head unit 71 which includes a dial assembly 72. The dial assembly 72 includes front and back plates 73 and 74 which are connected to one another through posts 75. The front plate 73 extends beyond the posts and is adapted to be attached by screws 76 to a rigid upright front plate 77 of the receiver chassis. The front plate 73 of the dial assembly 72 may desirably serve as a support for the entire head structure 71.

The back plate 74 is connected by screws 78 with a front housing member 79 which includes a solid and substantial rear wall 80. The wall 80 is formed with a marginal, circular collar portion 81 upon which a circular housing member 82 is adapted to be affixed through the medium of pins 83 which project outward from the collar portion 81, and bayonet slots 84 formed in a sleeve member 85 of the housing member 82. The plate 80 and the housing member 82 jointly form an air-tight enclosure.

A frame 86, rigidly affixed to the plate 80, supports in fixed positions all of the parts illustrated as contained within the housing 80, 82 with the exception of a flexible metallic diaphragm 87 which is affixed to the rear wall 88 of the housing member 82 and a yoke 89 which is affixed to the forward face of the center of the diaphragm 87. The purpose of the diaphragm and yoke will be explained presently.

The frame 86 comprises a relatively heavy base block 90 which is desirably formed integral with the plate 80, and which extends rearwardly from the plate 80 to a point near the rear end of the housing 80, 82. The base block is of generally rectangular construction, but is formed to provide an upwardly facing semi-cylindrical channel throughout its entire length save in the region of a rectangular cut-out 92 where the side walls of the channel are cut away.

A shield plate 93 is affixed to the lower face of the base block 90 and extends to one side thereof. Vertical plates 94 and 95 are united with one another to form a T-shaped frame unit which is supported from the base block 90, the

latter forming a shield between the tuned circuit assemblies of the mixer and antenna circuits.

All of the electrical parts diagrammatically illustrated in Fig. 1 are mounted on the frame **86**, but for the present the mounting and disposition of the parts will not be described in detail further than to show the physical disposition of the tuned circuit assemblies and the relation of the tuning cores to them.

Vertical clamping plates **96** and **97** are secured to one side of the base block **90** by screws **98** and **99**, respectively. These clamping plates are set into recesses of the base block, and extend upward alongside the adjacent vertical walls of the block to a level a short distance above upper coplanar horizontal end faces of said walls. Rabbets are thus formed by the upper ends of the clamping plates **96** and **97** which extend above the adjacent walls of the base block **90** and by the upper horizontal faces of said base block walls. Corresponding opposed rabbets **100** are formed at the same level in the opposite walls of the base block, so that the base plates of supporting units for the coils **35** and **28** may be set in the rabbets and clamped in place by the plate **96**, and so that the base plate of a supporting unit for the coil **10** may be set in the rabbets, and clamped in place by the plate **97**, with the hollow cylindrical coil forms accurately aligned in coaxial relation with one another.

The plates **96** and **97** will be seen to cooperate with the base block **90** to form C-clamps. The opposed jaws of these clamps extend parallel to one another and parallel to the axis of the channel in the block **90**. The base plates of the coils **35**, **28** and **10** may, therefore, be set and clamped in different selected positions longitudinally of the block **90**. Each of the plates **96** and **97** comprises an anchoring portion screwed into firm and unvarying electrical contact with the block **90** and a bendable portion extending therefrom which is always spaced from the block **90** throughout its entire length, so that circulating currents induced in the clamping structure are provided with an unvarying and unambiguous current path.

Cores **12** and **12***a* are mounted upon a ceramic thrust rod **111** for cooperating with the respective windings **35**, **28** and **10** in fixed positions longitudinally of the rod for controlling the tuning of the tuned circuit assemblies containing the windings in accordance with the longitudinal movement of the thrust rod **111**.

The dial mechanism, which will be described at a subsequent point, is designed to operate the cores **12** and **12***a* longitudinally for effecting tuning. Operation of the thrust rod **111** from the dial mechanism is so contrived that no air leakage joints are formed in the housing **80**, **82**.

The thrust rod **111** is supported in a bushing **112** carried by the plate **95**, and in a bushing **113** carried by the plate **91**, and is connected at its left-hand end, as seen in Figs. 3, 9 and particularly 5*a*, with a metallic bellows **114**, desirably of the Sylphon type which is affixed and sealed to the plate **89**.

A metallic thrust rod **115** aligned with the thrust rod **111** and adapted to be actuated from the dial assembly is mounted in a bushing **116** which is carried by the plate **86**. The push rod **115** carries an end plate **117** which is soldered to the end wall **118** of the Sylphon bellows **114**. At the opposite side of the wall **118** a threaded cup **119** is soldered to the wall. Motion is transmitted from rod **115** to rod **111** through an imperforate

wall of the bellows **114**, that is to say, through a completely sealed structure which does not depend for its sealing upon packing, glands or like sealing means, such as must be relied upon where a joint between relatively movable engaging surfaces is sought to be maintained.

The thrust rod **111** is provided with an enlargement **111***a* which has a circumferential groove **120** formed in it, as viewed in Figs. 5*a* and 9. A hollow threaded cap **121** is impaled upon the enlargement **111***a*, and a resilient split ring **122** is caught within the groove **120** and captured within the cap **121**. With the ring **122** thus captured within the cap **121**, the cap **121** is threaded onto the cup **119** to force and maintain the left-hand end of the thrust rod **111** firmly against the base of the cup **119**, so that the rods **111** and **115** are caused to move in unison as one unitary structure. The construction also serves to establish and maintain axial alignment of the rods **111** and **115**.

At the rear or right-hand end of the rod **111**, as seen in Fig. 3, the rod has affixed to it a metallic cap **122***a* having a circumferential groove **123** which is adapted to be received between inturned fingers of the yoke **89** of the diaphragm **87**. The cap **122***a* serves as a slide bearing for cooperating with the bushing **113**. A metallic sleeve **123***a* fixed on the rod **111** serves as a slide bearing for cooperating with bushing **112**.

As seen in Fig. 5*a* the cylindrical core **12***a* is held firmly between two shoulders which bear over the entire ends of the core, thus giving rise to no high unit pressures. The ceramic piece **111***a* establishes the distance of the core **12***a* from the end of the push rod **115**, and while it may be made integral with the rod **111**, due to manufacturing difficulties it may well be made as a separate piece cemented on as shown. Its ends are ground parallel to one another and normal to the axis, and care is taken when cementing that these faces are maintained normal to the axis of the rod **111**. Core **12***a* is then loosely slipped on the rod and the ceramic spacer **111***b* slipped on next. The outside diameter of this spacer is made slightly greater than the diameter of the core, since experience has shown that if the core rubs against the inside of the coil form some iron particles are rubbed off the core and permanently deposited on the inside of the coil form causing a change in frequency due to this wandering of the iron.

The next ceramic spacer **111***c* is then slipped on to establish a desired position of the mixer core **12** on the rod. Another ceramic spacer **111***d* is slipped over the rod subsequent to mixer core **12**, and a metallic sleeve **123***a* is rather tightly fitted over the rod at that point to cooperate with a sleeve bearing **112** screwed into the partition **95**. Another ceramic spacer **111***e* then determines the position of the core **12** which tunes the antenna circuit, and a ceramic spacer **111***f* determines the distance between the final core and the end cap **122***a*.

All of these cores and spacers are more or less a loose fit on the rod **111**, and they are maintained in relation by a thrust pressure developed by the spring washer **122***b*, which forces the whole assembly against the stop provided by the piece **111***a*. The end cap **122***a* which cooperates with the bearing **113** inset in the partition **91** is then forced on with some pressure and cemented in position.

The cement used to fasten on ceramic end cap **111***a* and metallic end cap **122***a* is out of the field of any coil, and if, due to cold flow or age this cement creeps slightly, say of the order of one-

thousandth of an inch or so, this will be taken up by the spring washer 122b, and the cores will not be altered in their positions relative to the abutment shoulder of cap 111a. While all of the spacer sleeves are of predetermined lengths within reasonable tolerances, it will be observed that the most important core, namely, the core 12a, which cooperates with the oscillator coil, does not depend upon any spacer sleeve for its position, but abuts at all times against the shoulder of the cap 111a. This point is stressed for the reason that variations which are tolerable with respect to the cores 12 would be highly objectionable with respect to the core 12a. The diameters of the spacers 111c to 111f have been made smaller than the cores solely to save weight which might give rise to inertia effects when the apparatus is used in locations where marked vibration and shock are encountered.

While the rods 111, the spacers 111a to 111f, inclusive, the base plates 166 and the coil forms 173 and the sockets of tubes VT1, VT2 and VT3 have been described as of ceramic material, it is to be understood that this term is intended to comprehend other insulating materials which have been found suitable such as glass and quartz. Plastics in general of either the thermo-plastic or thermo-setting type have been found unsuitable for this type of construction, with the possible exception of "Micalyx," due to their cold flow, their non-cyclic cubic change with temperature, and their often erratic changes of dielectric constant with temperature.

The rod 115 is thrust rearward by the dial mechanism, and in turn thrusts the rod 111 rearward with it against the predetermined, light, combined spring action of the bellows 114 and the diaphragm 87.

The reason for providing the bellows 114 and the diaphragm 87, however, as distinguished from a simple spring is that it is desirable that all the parts contained within the housing 80, 82 be kept as free as possible of the influence of humidity variations and of variations of atmospheric pressure. The bellows and the diaphragm constitute a portion of the means for completely sealing the housing 80, 82 from the atmosphere, and thereby eliminating variations of air pressure and limiting variations of humidity when the apparatus is taken aloft and returned to the ground on aircraft. It is especially important that many of the parts enclosed in the housing 80, 82 be guarded against the possible depositing of dew upon them.

In mobile, and especially in military use, where the apparatus may be serviced under conditions of high humidity, the air trapped inside the container 82 may well have such high moisture content that condensation will occur with subsequent lowering of temperature in the apparatus. It is desirable to remove the moisture content from the confined air by the use of a desiccant such as silica gel, contained in a small perforated container 131 (Fig. 8) which is held in place by a small spring bracket 132. The container 131 can be slipped into place just before the housing member 82 is put on.

The bellows 114 and the diaphragm 87 serve not only to avoid any air leakage joints in connection with the thrust rod operation, but they serve also to render the resistance of the thrust rod 111 to dial operation independent of atmospheric pressure, and, therefore, independent of variations of altitude at which the apparatus is operated.

The interior of the bellows 114 is open to atmosphere around the thrust rod 115, and the external face of the diaphragm 87 is intentionally exposed to the atmosphere through a small port 124 formed in the rear wall 88 of the housing member 82. The bellows 114 and the diaphragm 87 are designed to respond equally to changes of atmospheric pressure, and in respect of changes of atmospheric pressure they are opposed to, and balance, one another, thus forming a balanced piston arrangement. Whatever the atmospheric pressure may be, therefore, the dial mechanism is required to actuate the thrust rod 111 only against the simple combined spring action of the bellows 114 and the diaphragm 87 under all conditions of operation. The bellows 114 and the diaphragm 87 are desirably so designed that the bias of the thrust rod against the dial mechanism is always in the region of one pound.

It is to be noted that core tuning, as distinguished from variable condenser tuning, may conveniently be effected through limited travel of a thrust rod, as distinguished from operation of a rotary shaft, and, therefore, is well adapted for operation through air-tight connections as described. The fact that tuning is effected through operation of a thrust rod is, therefore, a very important factor contributing to the elimination of adverse humidity and pressure variations.

A rubber gasket 125, set in a rabbet 126 of the collar 81 is engaged by a shouldered portion 127 of the housing member 82 to establish a complete air-tight seal between the housing members 80 and 82. The housing members 80 and 82, which are of metallic construction, are also firmly connected electrically to one another through engagement of the sleeve portion 85 of the housing member 82 with the periphery of the collar portion 81 of the plate 80, and through the pin and bayonet slot connection of these members.

The pins 83 are irregularly spaced on the collar 81, and the bayonet slots 84 are correspondingly irregularly spaced in the sleeve 85, so that the housing member 82 and the housing member 80 can be united to one another only in a single predetermined rotative relation. The reason why this is desirable is that it is necessary that the push rod 111 be separable from the yoke 89 carried by the diaphragm 87, in order that the housing member 82 may be attached to and detached from the housing member 80 at will. The yoke 89 is turned with the casing member 82 as the casing member 82 is applied to the casing member 80, being carried in a circular path around the common axis of the housing members 80 and 82. It is important that the inturned fingers of the yoke member 89 shall be lodged in the circumferential groove 123 of the rod 111 by this rotary movement, in order that the diaphragm 87 may be caused to be attached to the rod 111 and to influence the action of the rod 111 in the intended manner. The fact that there is only one relative orientation in which the housing members 80 and 82 may be attached to one another assures that the yoke will be operated into the proper interfitting relation with the thrust rod 111 whenever the casing members 80 and 82 are united with one another.

It should be noticed that the housing members 80 and 82 will ordinarily be put together on the ground and that the change of pressure sought to be guarded against is that which arises from

carrying the apparatus into the air to an elevation where a substantially reduced air pressure is obtained. Under these circumstances, the pressure within the housing is greater than that of the surrounding atmosphere and the tendency is to force the diaphragm of the Sylphon bellows outward. It is not enough, therefore, that the diaphragm merely bear against an end of the thrust rod 111, but it must be so connected that it may exert a pull on the thrust rod to balance the opposite pull of the rigidly connected bellows.

In order that electrical connections may be run from within the housing 80, 82 to the parts of the apparatus located outside the housing, a terminal block 128 of insulating material is sealed in an opening 129 formed in the collar portion 81 of the plate 80. Conductive rods 130 pass through the block 128 and project beyond the inner and outer faces of the block, the rods being sealed in the block in an airtight manner and providing posts at their inner and outer ends to which electrical connections can be made.

The block 128 is desirably formed of a suitable insulating plastic material such as Bakelite. An enlarged portion of the block is disposed within the housing 82 and bears against the rear or inner face of the plate 80. A continuous sealing groove 128a is provided in the rear face of the plate 80 in the area covered by the enlarged portion of block 128, and this groove is filled with a suitable cement for sealing the joint between the block 128 and the plate 80. The cement employed is desirably characterized by the fact that it never sets throughout the wide operative temperature range, but instead remains permanently in a viscous, semi-fluid condition.

Figs. 10 to 19, inclusive, disclose tuned circuit assemblies and parts thereof, each employing a cylindrical coil form and a solenoidal coil wound thereon.

Referring to Figs. 10 to 12 and 17, the means for supporting the coil 35 and its associated condenser is shown as comprising a generally rectangular shaped plate 166 molded of ceramic insulation material and having formed therein three cylindrical holes 167 and a pair of elongated slots 168. Centrally of the block at its front and rear it is provided with arcuate shaped portions 169 and 170 from which depend the short tapered tongues 171, and between the arcuate portions 169 and 170 the middle portion of the plate is undercut in an arcuate shape as indicated at 172. The entire plate is finished to the shape shown by a molding operation and is then baked at a high temperature.

Referring to Figs. 13 and 14, the coil supporting form 173 is shown as comprising a generally cylindrical shaped tube composed of the same ceramic material of which the plate 166 is formed. The coil form has a spiral shaped groove 174 ground therein adapted to accommodate the coil 35 which is herein shown as comprising a thin metallic ribbon 175 of two turns (see Fig. 15), which may be heated when applied to the coil form, so that it may develop tension through shrinkage as it cools. The coil form is also longitudinally slotted as at 176, the slot being tapered to accommodate the tongues 171 so that the slot 176 and tongues 171 provide means for locating the coil form in a definite position on the supporting plate 166. A material which will glaze is applied to the portions of the coil form and plate 166 which are to be brought into contact with each other and the members then baked to glaze the material which thereupon unites the supporting blocks and coil form into a unitary rigid stable assembly. The ceramic material is preferably of such a nature that its surface contains a large number of small particles which project beyond the general surface level and puncture the skin of the ribbon 175 in numerous places, thereby entirely preventing any slippage of the ribbon on the coil form. The result is that the coil is maintained tightly in engagement with the coil form at all times and does not change in shape due to any changes in temperature or humidity. In other words, the coil and coil form are, as it were, locked together throughout the full length of the coil and the size and shape of the coil remain at all times the same as those of the coil form. This arrangement obviates any non-cyclic variation in distance between one turn of the coil and another and also any non-cyclic variations in the diameter of the coil so that once the coil is wound, its inductance thereafter is not subject to non-cyclic variations due to temperature or aging. The ribbon of the coil is desirably a semi-elastic material such as sterling silver. Such material combines with high conductivity a softness permitting ready penetration by the coil form crystals and an elasticity capable of maintaining the required tension. Pure silver has been found unsuitable because it does not have the required elasticity.

Referring to Figs. 16 to 19, the powdered iron slug 15 is secured against the lower surface of the block 166 by means of a pair of screws 177 which pass through the slots 168. The inner face 178 of the slug 15 is arcuate in shape so that it may be moved inwardly into engagement with the surface of the coil form 173. The manner of adjusting the position of the slug 15 for controlling the slope of the tuning curve of the oscillator will be hereinafter described. The left-hand end of the ribbon 175 is soldered to an inwardly extending tongue 179 formed on a metallic coil terminal 180 which has a flat portion 181 held against the lower face of the block 176 by a threaded hexagon head screw 182. The width of the tongue 179 is substantially equal to that of the groove 174 in the coil form so that it engages the sides of the groove and thereby prevents the coil terminal 180 from rotating when the screw 182 is tightened up. Coil terminal 180 is also provided with a depending lug 183 whose lower edge is provided with an arcuate surface 184, Fig. 17, adapted to engage and be soldered to a metallic cylindrical coating or thin sleeve 185 secured to the outer peripheral surface at one end of a thin tube 186 formed of insulating material (see Figs. 18 and 20). A similar but somewhat smaller metallic coating or sleeve 187 is provided near the other end of tube 86 and the interior of the tube is provided with a thin metallic coating or sleeve 188, so that the entire unit forms an electrical condenser.

The coil terminal 189 for the other end of the coil is similar in construction to coil terminal 180, except that its parts are reversed, and corresponding parts of the two terminals are designated by the same reference numerals. The tongue 179 of terminal 189 is secured and soldered to the other end of the ribbon 175 and the arcuate surface 184 of its depending lug 183 is in engagement with and soldered to the coating 187 of the condenser. The mid-tap 53 (Fig. 1) of the coil is soldered to a tongue 190 formed on the center terminal 191 whose main body portion is flat and is threaded to receive the securing screw 192.

The tongue 190 extends substantially the full width of the spiral groove in the coil form, thus preventing rotation of coil tap 191 when the screw 192 is tightened. The upper ends of the hexagon securing screws 182 and 192 are rounded off as indicated in Figs. 17 and 18 at 193, thereby providing switch contacts for the coil and condenser assembly. It will be noted that the condenser construction described forms the condenser 60 of Fig. 1 of fixed value and which is connected across the ends of the oscillator coil 35, and that the securing screws 182 and 192 form the switch contacts 44, 45 and 55 of said figure.

In the tuned circuit assemblies described, a ribbon having a thickness of about three mils and a width of fifty to seventy mils may be advantageously employed. These dimensions are cited by way of example, however, and not as defining practical limits.

Since high sustained accuracy is sought for, no structure or material can be used except of the most unchanging nature. Physically, glass, quartz and ceramic are most suitable insulating materials and have good retrace characteristics of dielectric constant and physical size when varied with temperature. No structure can be employed where there is the slightest possibility of any permanent change to any degree, either electrical or mechanical.

The type of tuning employed is of the core type, and while ferrous cores will be mainly discussed, the conductive type core, as for instance silver or copper, may well be used in some applications.

The tuned circuit must, therefore, be designed with the requirements of core tuning in mind. It is basic, however, that before we can tune the circuit over a range, the circuit without such tuning means must in itself maintain a fixed frequency to a high order of accuracy. It must also allow trimming, tracking and aligning with a precalibrated dial having great length and accuracy of resetting. It must have no wiring at all.

The coil is first considered. Its design must allow use of one to four turns, for example. It must allow bringing out a tap to any turn or fraction of a turn. Its external tuned circuit must include a tuning condenser having minimum inductance, and the whole outside return loop must be minimized.

The concentration of over 90% of the inductance is actually in the coils of the tuned circuit assemblies described where it is capable of being acted on by a core.

The diameter of the coil is chosen to be about 405 mils in the present instance for use with a 375 mil core. Considerable difficulty is had in the ceramic art in making thin walled tubes beyond a certain minimum thickness of wall. Maximum tuning ranges obtainable with coretuning are reached where the core substantially fills up the coil, but it must still freely pass through the bore of the coil form. If we chose this same ratio with a 125 mil core, the wall thickness would be less than 5 mils, an impracticable figure for quantity production in the present state of the ceramic art.

The coil form is made with grooves for receiving the conductor. The form is thin in the grooved portions and thick in the ungrooved portions. The thick portions support the thin portions during firing, and also provide guiding side walls for the grooves.

Since the conductor chosen must have high conductivity, its thermal coefficient of expansion must also be high, at least two or three times that of the coil form. A spiral winding inherently has no strength of its own, so it must be the mechanical slave of the coil form. This means the wire must be wound under sufficient tension and have enough elasticity to cling to the form at the most adverse temperature.

The cross-section of the conductor is a very thin strap, rather wide. If large, round conductors are used, such as #14 round wire, the current tends to hug the coil form as it is the smallest diameter of the turn. Any good conductor has a large temperature coefficient of resistance, however, and if the temperature be raised the resulting increased resistance causes a redistribution of the current, causing the diameter of the mean current path to be increased. This markedly increases the inductance, since diameter of the current path is square in the formula for the inductance coil, and great changes in frequency result.

By using a very thin strap of the order of three mils in thickness, this effect is minimized and a disciplined current path results. Instead of using pure silver, sterling silver is used for greater toughness and elasticity and may be wound on the form quite hot by passing a heavy current through it while winding, in which case it shrinks on the form. Tension may be used also, sufficient to stress it nearly half way to its elastic limit so it hugs the coil form like a rubber band.

Silver plated "Invar" or "Nilvar" used in large cross-section maintains its cross-section under temperature variation, but the current redistribution is the same as for pure silver, and it must be wound under tension and in general has no advantage over the thin sterling silver strap, which may be flattened wire.

It is of great advantage to use ceramics of the low loss type such as Alsimag 196 because of the presence on the surface of minute sharp crystal structures which apparently pierce the skin of any unhardened metal pressed firmly against them. Repeated temperature cycling of these coils from −40 to +217° F. show no creepage of the winding, since each unit length is captured by its adjacent crystals and held firmly in place.

The length of coil chosen must also depend in part upon the tuning curve desired and upon the length of core travel most easily obtained with a desirable dial mechanism such as the movement shown in Figs. 2, 26 and 27. A coil 375 mils long, measured center of winding strap to center of winding strap gives an active core movement of about 250 mils for 25% tuning range.

In any coil to be used with a core the inside of the coil form must be left free to pass the core. Most methods of terminating coils use rivets, eyelets, or passing the conductor through holes in the form, all of which would interfere with core movement. Some structure outside the simple cylindrical coil form is, therefore, required. This takes the form of the plate or block 166 with its associated terminal blocks 130, 189 and 191 (see Figs. 17, 18 and 19).

The block 166 is preferably glazed to the coil form. Plastic cements are undesirable because of cold flow and change with age, but a good glaze in the joint fired at 1700° really makes the two pieces unitary.

Plate 166 allows use of massive structures such as blocks 180 and 189 to be employed to give a rigid and definite termination of the inductance

at either end. These blocks are given large cross-section so that they will have a minimum possible inductance, and the tongues 179 provide exact termination of the inductance wound on the form, in that the take-off of the current is normal to the axis of the coil. Each tongue 179, being the full width of groove 174, provides a rigid non-turning structure when the contact screws 182 are tightened up. Shaping of these blocks to include the turned up portion 183 (Fig. 18) allows a condenser to be included for tuning the circuit.

A number of assemblies have been assembled and tested using the condenser 60 of Fig. 20, which is a commercial form where the capacity may be formed between the inner plate 183 and the two bands 187 and 185 forming two condensers in series, or the outer band 185 may be continued around the end of the hollow cylinder joining the inside plate 188 forming a singled condenser through the ceramic body 186.

When this condenser is laid in the cradle formed by the connecting blocks 183 it will be seen that an absolute minimum inductance return path closing the physical separation between the ends of the coil proper has been achieved.

It is found to be a considerable advantage in this self-contained structure that rounded contacts 193 can be used as a switch in the case of multi-band apparatus. There is a real problem in switching ultra-high frequency circuits where the switch is placed within the tuned circuit. A coil in the broadcast band may easily have an R. F. resistance of 5 ohms, or 5000 milliohms. A satisfactory commercial type of small switch may have contact resistances of 5 to 40 milliohms, which is negligible in proportion to 5000 milliohms. A two-turn coil such as shown in Fig. 18, however, may have a total R. F. resistance in the entire tuned circuit of only 40 milliohms, and consequently the contact resistance of any practical form of switch, which of necessity must be small because of the small physical dimensions of these circuits, becomes a substantial portion of the total resistance. It is an advantageous feature of the present invention that each coil carries its own tank condenser with it, allowing switching of the charging current to the electrodes of the tubes only, a much easier matter.

Provision of these contacts also allows desirable slipping of the whole tuned circuit assembly axially. The advantages of this slipping will be more fully discussed when the alignment of the set is described.

Provision of the plate 166 also allows for the use of a solid block trimmer 15 as shown in Fig. 17.

Plate 166 also provides a fastening means for the assembly as shown in cross-section in the oscillator, Fig. 21. As mentioned previously, the ultra-high frequency ceramics used have the surface property of sharp crystal structures which are able to pierce the skin of any reasonably soft metal by simple pressure. Advantage is taken of that fact by having the tuned circuit assembly holder form a C clamp. The clamp shown, when fully tightened, gives a surprising result, in that the entire set may be lifted by the tuned circuit assembly 34 with absolutely no shift in the position of the tuned circuit assembly. By loosening screws 98, however, the tuned circuit assembly 34 may be readily slid back and forth axially while maintaining strict alignment between the bore of the coil form and a core surrounded thereby. It has been found that tightening up the screw 98 again causes no shift in the position of the tuned circuit assembly and provides a positive lock against shifting due to any shock or vibration or thermal working.

The necessary provision for a tap on the coil is met by the provision of the third contact 192 (Fig. 18), the block 191, and the tongue 190 engaging the coil.

In a practical receiver using this type of gear, the problem of injecting the oscillator voltage into the mixer circuit is accomplished by coaxial mounting of the two assemblies, a distance between them being chosen to give the desired amount of oscillator injection into the mixer grid circuit, for instance.

Tracking between the oscillator and R. F. circuits may be accomplished by any one of several means, for example, by selection of the diameters of the cores for tuning the circuits. One circuit tunes over a greater percentage range than the other circuit, depending on whether the oscillator is run at a higher or lower frequency than the signal. The ratio of the two diameters of the cores is a function of the frequency separation, desired to give the necessary intermediate frequency, which in this receiver was 5.2 megacycles, but which may well be anywhere between one megacycle and twenty megacycles.

The tuned circuit assembly shown in Figs. 16 to 19, makes provision of a single unit that has in effect fastening means, tuning means, switch, tank condenser, trimming, tracking and aligning means in a single simple structure. All the frequency determining elements are well within a cubic inch, and are affected simultaneously by conditions of temperature, vibration and shock. There is no influence of the chassis upon the frequency. There is thus provided a unit that can be used either for transmitter, receiver, wave trap, or any of the numerous uses to which tuned circuits can be put.

The Q of these assemblies is found to be quite high without the core. If measured in air without any associated apparatus, the Q is about 700. When measured in the coil holder and with an oscillator tube assembly attached, as shown in Fig. 21, with the tube in place but not lit, the Q exceeds 400.

A further advantage of this type of construction is that no parasitic loops of any kind are formed to give resonant absorptive effects or resonant voltage rises at any frequency within the operating range of the current acorn tubes, and in no case below 1500 m. c.

Since an oscillator is by all means the most difficult unit to design in regard to frequency stability and resettability, great attention must be paid to all elements cooperating with this basic circuit to give a complete oscillator. Referring to the wiring diagram of Fig. 1, it will be noted that the ultraaudion oscillator is used, which is the simplest form of all such circuits. Elimination of the center tap might have been accomplished by shunt feeding the plate through a resistance. Such an arrangement is not considered most advantageous, however, because of the wattage dissipation and the voltage drop in such a resistor. Since it is desired to maintain the universality of application of this unit, it is often desirable to operate with such low plate voltages, as for instance in the battery type of acorns, that 20 volts drop in the plate shunt resistor would force the use of a higher voltage battery.

An approximate center tap shown has an isolation resistor 57 associated with it, since with core tuning with the core introduced at one end

the null point (that point which is at zero potential to ground) shifts as the core is inserted. This shifting null is taken care of by the resistor, which prevents any substantial radio frequency energy from flowing down to ground through the plate energizing connection.

The ultraaudion circuit has the advantage that the cathode and heater are at ground potential, thus eliminating frequency fluctuations introduced by way of the cathode to heater capacity, when the heater is energized from an alternating or fluctuating source of voltage.

It has been found that the capacity ratios between the electrodes of the acorn tube as now manufactured, both battery and 6 volt types, is very nearly ideal for this type of oscillator. The assembly shown in Fig. 21, when operated from a power source which varies from 20 to 30 volts gave a total frequency shift of 7 kc. at 132,000 kc., with a tuning condenser of 15 mmf.

The high potential portions of the circuit **34** of Fig. 1 (and also Fig. 5 and Figs. 21–24) are the three connections **43**, **46—47** and **56** on the end of the socket shown close to the tuned circuit assembly **34**. No wiring whatsoever is used in this whole assembly, and consequently no resonant loops can be formed. All the circuit elements shown in Fig. 1 are present in Figs. 5 and 21 to 24. The plate connection is directly to one end of the tuned circuit assembly **34** through a simple metallic contact **43**. The other end of the tuned circuit assembly **34** makes connection through a grid condenser **47**. This grid condenser, which is also a nut for holding fast the terminal contact **227** on the socket **228**, is armored with a silver cup **224** to stand the abrasion of its use as a switch contact, and is also the holddown for the grid leak **49**. This condenser desirably has a value of 25 mmf.

The acorn socket **228** is that disclosed in U. S. Patent No. 2,290,306, granted to me on July 21, 1942. The socket **228** is mounted in this assembly so that a spring **229** forces it down against the switch contacts **44**, **45** and **55** of the tuned circuit assembly, but the socket has great lateral rigidity in its mounting. The center contact **56** is mounted on a blank hole in the socket **228** as shown, and must be resilient as shown, since it is practicable to line up two rigid contacts, but not three. The resistor **57** in the B lead and the grid leak **49** are of the type wherein colloidal carbon is baked onto a glass thread, and are almost free of capacity effects. Because of their resistance, such resistors cannot form portions of resonant circuits. They are terminated in the condenser network shown which is described elsewhere as the universal type of bypass condenser **23**, and lugs are brought out at the bottom to connect to the embedded resistors **50**, **58**, **230** of the wire wound type shown in the assembly, thus acting as radio frequency chokes as well as resistors. The cathode and one side of the heater are connected to ground by a plate **231** pressed flat without insulation against the bracket **95***a*, and the other end of the heater is brought out through a similar plate **23** isolated on either side with mica sheets, and brought back through the bracket **95***a* to pick up its appropriate resistor **230** buried in the bracket **95***a*. The outer plate **229** of this assembly is grounded through the mounting screws **232** and is made of heavy Phosphor-bronze to form a spring of great strength to force down the socket onto the contacts of the tuned circuit assembly.

The design of the resilient contact **56** must include a fundamental design requirement which can perhaps be more readily understood in connection with the C clamp jaw **96** of Figs. 21 and 23.

Where it is necessary to maintain the frequency of a tuned circuit to a very high degree of accuracy through wide ranges of temperature, it is necessary to avoid having one curved piece of metal tangent to another where the point of contact may be somewhat doubtful. Under thermal stress wide variations in current paths can be expected in the currents induced in all such members surrounding tuned circuits. As shown in connection with **96**, there is provided a definite line of contact held firmly by the screws **98**, and a full clearance above that line of contact, so as the jaw **96** bows under the thermal stresses it offers an unchanged current path to circulating currents that may be induced into it.

Examination of Fig. 21 shows how the tuned circuit assembly **34** may be readily moved axially over a rather short distance such as a thirty-second of an inch, to take up tolerances and allow alignment of the circuit with a pre-engraved dial. It can also be seen that coil holder **90** and one associated oscillator tube assembly may be used at almost any desired frequency, say from 3 mc. to 600 mc., by inserting a complete tuned circuit assembly **34** having its inductance and capacity suitably chosen to operate in the portion of the spectrum desired.

In distributed capacities, an assembly of this nature is exceptionally low. All capacities, including the tube capacities, other than the tank condenser **60** itself, average about 3.8 mmf. A two-turn coil such as shown in Fig. 18, with the tank condenser omitted, will oscillate at 400 mc., showing that, when the tank condenser is inserted to bring its frequency down to an operating range in the neighborhood of 150 mc., we have a highly disciplined circuit of great stability.

The bracket **95***a* is shown in Fig. 21 as firmly screwed to the block **90**, by screws **233**, but may well be spot welded, if desired. The first time after these assemblies are put together they have a rather large drift in frequency as they are given a thermal run, but the second run shows they have steadied down and reached the condition of mechanical equilibrium. In fact, thermal cycling beyond two times seems to be hardly necessary.

It is highly desirable that the core have almost no temperature coefficient of its own, as otherwise either incomplete or very elaborate compensating means would have to be used. Cores of the ferrous oxide type, while having very low losses at frequencies in excess of 100 mc., have marked temperature coefficients of both permeability and losses. Certain cores of the carbonyl produced type, however, are found to have a very high order of stability, both in regard to losses and permeability, when used at these frequencies. Great care is necessary in insulating and binding these spherical particles together, and particles must be chosen having differentiated internal structure, such as being formed of a plurality of concentric shells. The losses are markedly higher than those in the ferrous oxide type, but the cores are still decidedly usable. Total thermal drifts of 10 to 20 kc. at 100,000 kc. can be reproducibly obtained with this type core, when heated to several hundred degrees.

The dial mechanism shown in Fig. 3 can be designed to maintain the relative positions of the coil and core throughout a wide range of temperatures as is described in my copending applica-

tion, Serial No. 464,812, filed November 6, 1942, covering the dial mechanism. As is pointed out therein, we are not interested in the distance of the core or the tuned circuit assembly from the panel 74 of Fig. 3, but only in their relation to each other. The tuned circuit assembly is caused to bear a determinate relation to said panel 74 through the one piece die casting 79, 90, and as the temperature increases will move away from panel 74 in accordance with the thermal coefficient of expansion of the die cast metal. The core 12a, Fig. 3, has its position determined in relation to panel 74 through a more complex mechanical system, but, if the materials of which this path is composed be properly chosen, they will have identical effect in moving core 12a back from the panel 74 as the main die casting 79, 90 has in moving back the coil structure in response to temperature changes.

Suitable ceramic condensers may be employed of the type that have very small temperature coefficients of dielectric constant, and are quite satisfactory.

There are numerous advantages in having a straight line relationship between the amount of displacement of a core which controls the frequency of a resonant circuit and the resonant frequency produced. For example, it may be desired to cause an increment in frequency of exactly one megacycle with a core movement of exactly 10 mils (.010''), and to have this relationship hold over as wide a tuning range as possible as, for example, from 110 mc. to 135 mc.

Among the advantages of such an arrangement are that the use of an essentially linear dial and movement such as shown in Figs. 3, 5, 26 and 27, is possible, and that it permits one resonant circuit to be readily tracked with another in cases where a definite relationship, such as a constant frequency difference, is to be maintained between the resonant frequencies of the two circuits. In tuning a circuit over this frequency range it has been found practically desirable, because of physical limitations, to arrange for a total core movement of the order of ¼ inch, as giving the best balanced design in this instance.

Through proper design of coils and cores S. L. F. (straight line frequency) may be obtained over a very substantial and practical range as more fully disclosed in application Serial No. 468,195.

Where it is desired to precisely adjust the resonant frequency of an oscillator or other resonant circuit to a single predetermined frequency, the capacity and inductive elements of the circuit may be made to tune to this frequency as close as practical considerations permit, leaving the precise adjustment to the correct frequency to the manipulation of the slug 15. It will, therefore, be seen that a single self-contained unit as shown in Fig. 21 in the absence of the movable core 12a permits radio apparatus to be built to resonate at a single assigned frequency in a very simple, compact and stable form.

The oscillator assembly of Fig. 21 is shown as part of a complete radio receiver (Figs. 3, 5 and 8). The receiver shown has an R. F. stage and mixer assembly. Transmission line input 2 is shown going through the contacts 3 and 4 to the first tuned circuit 9. The coil of tuned circuit 9 is tapped at an impedance point to match the transmission line, usually about a quarter turn from the grounded end of the coil 10. The high potential side of tuned circuit 9 is brought out through contact 5 (Fig. 5) and forming part of said contact is the grid condenser 20. An insulating block shown supports the grid leak 21, and the bottom end of the grid leak is connected to its bypass assembly 23.

The R. F. amplifying tube VT1 herein shown as the acorn type, has associated with it its bypass condenser 23 which bypasses the screen of VT1 to ground. This socket is mounted on the partition 95 which forms a shield between the input and output of the R. F. stage as indicated by dotted line 33 in Fig. 1. The plate of VT1 is connected to the top of tuned circuit assembly 24 through contact 25 and the low potential end of tuned circuit 24 is connected to an R. F. ground provided by contact 5 and its associated bypass assembly 23. Plate energizing potential is also supplied through this contact. The grid of the mixer tube VT2 is usually tapped down on the coil of the assembly 24 somewhere between one-third and one-half from the top end of the coil and is brought out through contact 30 of grid condenser 37 (see Fig. 5), and its grid leak 38 is mounted on the insulating support shown and is brought out through its bypass assembly 23. The socket for the mixer tube VT2 is mounted on a partition 94 parallel to the axis of the coil holder 90 and has associated with it its own screen bypass 23. This method of bypassing the socket is more fully brought out in my issued Patent No. 2,290,306, granted July 21, 1942. The plate of VT2 is immediately adjacent to tuned circuit 40 (Figs. 3 and 8), and since the radio frequency energy should have a very short path to ground, which is, of course, through the condenser portion of tuned circuit 40, the mechanical arrangement of the parts shown assures the lowest possible impedance path for the energy of the signal frequency which appears in the plate of the mixer to be effectively grounded through the conductive pillar 40a and its associated bypass 23 (Fig. 8).

The inductor of tuned circuit 40 is arranged to be permeability tuned to resonance with the desired intermediate frequency, and has coupled to it the transmission line 41, which can be of any reasonable length to carry the intermediate frequency energy to the rest of the receiver, which in some cases may be at some distance from the head as shown in Fig. 3.

The base 40b of Figs. 3 and 8 is made thick enough to contain resistors such as 22, 32, 39 and the filament resistors shown in the circuit diagram of Fig. 1 to provide isolation and choking action as described in connection with Figs. 44 and 45.

The curves of Fig. 25 have to do with the alignment process of the receiver. It must be kept in mind that with the type of dial employed in the illustrative receiver there is nearly a foot of dial per megacycle of tuning. The abscissas of these curves which are marked "Dial calibrations" represent, therefore, a scale of such length that the slightest inaccuracy of the receiver's calibration can be easily observed.

The first operation in lining up the receiver is to use the mixer tube as a detector, and introduce a signal into the antenna circuit, preferably at some mid-frequency, as for instance in this case, 122,000 kc. By loosening slightly the screws 98 and 99 shown in Fig. 5, the antenna and mixer tuned circuit assemblies 9 and 24 of Fig. 1 may be slipped until the signal is properly tuned in. Since these circuits are so heavily loaded by the vacuum tube input loading at these frequencies, their curves are rather broad, and this is not

a too precise adjustment, as we have shown by making curve A, which represents the R. F. circuit tuning as a double line, showing that a certain tolerance is allowed in their setting. Experience has shown that in many cases no further adjustment is required of these two tuned circuits, but if, due to some special use it is desired to align them more rigidly, the procedure now to be described in connection with the oscillator may well be used.

By tightening up the screws 99 of Fig. 5 the antenna circut is now locked in position, and the alignment of the oscillator commences. It will be noted that severe interaction between the adjustment of the mixer circuit 24 and the frequency of the oscillator circuit 34 occurs, since they are coaxially mounted with a rather small separation. In practice this means little since the mixer circuit 24 can be aligned and locked up before the oscillator is touched.

The mixer tube is reconnected as a regular mixer, and the oscillator lined up. in this case 5 megacycles lower than the signal. The actual receiver has an intermediate frequency of 5.2 megacycles, but to simplify the present discussion we will assume the oscillator frequency is exactly 5 megacycles lower than the signal frequency.

The two outer lines CL show in somewhat exaggerated form frequencies between which the oscillator will lie due to commercial tolerances in the items used in the physical construction of the apparatus. In practice these limits would probably lie somewhat within the limits of plus and minus 1%. The following process will line the receiver up with the dial better than .002%.

Curve B represents a possible curve for the oscillator within the limits CL. By referring to the ideal final curve D, it will be noted that this initial curve B is in error at both ends, and also has the wrong slope. It is inherent in the design of the circuits, however, that this line is straight.

A beat frequency oscillator is temporarily associated with the reeciver's intermediate frequency to allow the exact adjustment of the oscillator to curve B against a frequency standard by the well known process of zero beat.

In the factory alignment process, curve B would not be plotted, but would be handled according to the following procedure. A signal of exactly 135.000 kc. would be introduced, and the dial set at 135,000 kc., the most withdrawn position of the ferromagnetic core. The set has been assembled with the oscillator tuned circuit assembly 34 as far toward the rear of the set as is reasonably practical. It would now be slowly forced forward into increased engagement with the core until the signal is tuned in to approximately the zero beat, as is shown by the circle E. It will now be seen that curve B has been slipped down to form curve C, which is parallel to B, and now starts at approximately the correct place at the high frequency end, but has insufficient slope. The tuned circuit assembly 34 is now locked in place by tightening the screws 98.

The process now continues by introducing a signal of exactly 110,000 kc. and setting the dial for 110,000 kc. The iron slug 15 has been assembled midway in its travel, that is, neither tightly up against the coil form 173, Fig. 17, nor in the fully retracted position. Screws 177 are now loosened, the block 15 retracted to its fullest extent, and then slowly pushed toward the coil form until the precision signal is fairly well tuned in. As previously explained at length, the action of the slug 15 is to shift the slope of the tuning curve. Consequently curve C has now come very close to curve D. The dial and signal are now reset to 135,000 kc. to see if that point has been shifted. If so, the process is repeated to closer limits until curve D is fairly well attained.

It will be noted that we have not described the use of very precise tools in this alignment process, such as would be necessary for instance to slip the tuned circuit assembly 34 to a final resting place accurate to a small fraction of one tenthousandth of an inch. As a substitute means for attaining this necessary precision adjustment the mechanism of the dial is employed.

The dial mechanism is that disclosed in my copending application Serial No. 439,509, filed April 18, 1942, for Device for adjusting or tuning to close limits, and further incorporates the improvements disclosed in my copending application Serial No. 464,812, filed November 6, 1942, for Device for tuning or adjusting to close limits.

The dial mechanism comprises an operating knob 250 which is fast on a shank 251 of a lead screw 252. The shank 251 is revolubly mounted in front plate 73 (see Fig. 3) and in a cup shaped frame member 253 which is affixed to the back plate 74. A collar 254 affixed to the shank 251 has fast with it a dial 255 calibrated from zero to 1000 kc. The dial 255 turns in unison with the knob 250 and the lead screw 252 and, therefore, shows the setting of the lead screw.

The lead screw 252 is threaded through a nut 256 which is mounted in the back plate 74 and secured to the latter by screws 257. The lead screw 252 is provided with a nose 258 of hard facing metal for engaging and coacting with a distance or spacer cam 259. The spacer cam 259 is mounted with freedom for rotation and axial movement upon a fixed shaft 260 which has a force fit in a recess 261 of plate 80. The cam 259 transmits axial motion of the lead screw to the push rod 115 upon which the several tuning cores are mounted.

The cam 259 is itself adapted to be set to any one of twenty-five different selected positions, and in each of these positions it is designed to interpose a different predetermined thickness between the nose 258 of the lead screw and the forward end of the push rod 115.

The purpose of the cam 259 is to change the tuning by exactly one megacycle for each step of cam setting, the lead screw operation then supplementing the cam setting to provide continuous coverage between the stepped or discontinuous settings of the cam.

The cam 259 is operated from a knob 262 fast on a shaft 263, the shaft being revolubly supported in the front and back plates 73 and 74 of the dial unit. The shaft 263 has pinned to it a gear 264 which drives a gear 265 fast on a shaft 266. The shaft 266 is mounted in a bushing 267 carried by the plate 74. The shaft 266 also has fast upon it a gear 268 which is in mesh with a gear 269, the latter gear being fast with the cam 259.

The gear 265 drives a gear 270 which is revolubly mounted upon frame member 253. A dial 271 is affixed to the gear 270 in any suitable manner as by rivets 272 for showing the setting of the cam 259. The dial 271 is disposed behind the dial 255 in immediate proximity to it. The dial 271 is of larger diameter than the dial 255, so that only its marginal portion is exposed to view. The marginal portion of dial 271 is calibrated and marked in megacycles.

The cam 259 is a part of a cam assembly 273 which is best illustrated in Figs. 26 and 27. The cam assembly will be briefly described and its use will be more fully explained in connection with the further description of the lining up process.

The cam assembly comprises a central bearing sleeve 274 which is externally threaded at its rear end and is provided with a circumferential flange 275 at its forward end. The other elements of the cam assembly including cam 259, itself, are mounted upon the sleeve 274. These parts, while shiftable longitudinally of the shaft 260 are connected to form a unit and to travel rotatively and axially in unison with one another. The gear 269 is mounted upon the sleeve 274 adjacent the flange 275. A disc 276 of spring metal is slotted marginally to form twenty-five individual spring fingers or sectors 277. The disc 276 is disposed between the gear 269 and the cam 259, and the assembly is held firmly together by a nut 278 threaded on the sleeve 274.

The spring fingers 277 bear against thickness tapered adjustment blocks 279 which may be made of steel, such as type 440 stainless, and which are hardened and micro-finished on their working faces. The construction and function of those blocks will be more fully described presently.

Each step or sector into which the cam 259 is divided is provided with a hardened steel ball 280 which protrudes slightly beyond the rear face of the die cast body of the cam 259 for engaging the forward end of thrust rod 115. When assembling these balls with the cam 259, the cam is set in a hydraulic press and each ball is dropped into a cylindrical opening having a hemispherical bottom which is formed in the rear (now upper) face of the cam. The press plunger then descends and forces each ball to a predetermined depth, so that the high point of its protruding surface is at a predetermined distance from the forward (now bottom) face of the cam. This operation causes cold flow of the metal of the cam 259 so that the cam metal is caused to conform substantially to the contour of the ball. At the same time the ball is swedged in place by the press plunger. The protruding ball faces do not stand in a common plane, but, beginning with the ball in the thinnest sector of the cam, each successive ball is displaced rearward relative to its neighbor next lower in the series by 10 mils, to an accuracy equal to plus or minus ¼ mil.

In each of the twenty-five steps or sectors of the cam at the forward face thereof, a parallel-sided groove 281 is formed, having a sloping base or bottom wall 282. The bases of the grooves are plane and form segments of a frustum of a regular pyramid, in this case having a slope of 2°, and sloping forward toward an apex located in the axis of shaft 260. The thickness tapered adjustment blocks 279 are preferably given in inclination complemental to the inclination of the bases 282 of the grooves 281.

As a block 279 is slid into one of the grooves 281, its forward face extends continuously at right-angles to the axis of the sleeve 274, but it is progressively displaced forward to change the effective thickness of the cam between such forward face of the block and the high point of the protruding face of the ball 280 which is in the line of thrust with it. The complementary angles of slope of the block 279 and the bottom wall 282 of the groove 281 can be chosen from a considerable range, so that a wide variety of possible ranges of thickness adjustment is available. The 2° taper in this case allows a range of adjustment of slightly over one mil.

A leaf spring 283 is associated with each thickness tapered adjustment block and slid into the cam groove 281 with it. The leaf spring 283 comprises an inner straight arm 284 for engaging the inner end of the block 281, an intermediate bowed body portion 285 which extends alongside one edge of the block, and an outer curved portion 286 which extends around the outer end of the block and bears against such end. As the block and spring together are forced into the groove, the bowed intermediate portion of the spring bears against one side wall of the groove 281 and indexes the block against the opposite side wall of the groove. The friction of the spring 283 and of the block 279 against the side walls of the groove serve to retain the block in any position to which it may be adjusted. The block is indexed against the bottom wall 282 of the groove by the associated spring finger 277. Because of the very small angle of 2° chosen in the present instance, the spring fingers 277 and the spring 283 have thoroughly adequate holding power, so that the blocks do not shift in any direction after adjustment.

The forward end of the thrust rod 115 is formed with a groove 283*a* for cooperating with the balls 280 of the cam 289. Having in mind that the diaphragm 87 and the bellows 114 always urge the rod forward against the cam 259 with a force of about one pound, it will be seen that the balls 280 and the groove 283*a* have a detent action. The cam 259 and the dial 271 are therefore operated through steps of mechanically determined extent and are held against accidental shifting in set positions.

The dial mechanism is used for the final alignment of the receiver in a manner which will now be described. A threaded adjustment tool 287 is provided to screw into an opening 288 in the cam housing 79. The shank 289 of the tool 287 is reduced to provide a tip 290 which is of a dimension small enough to push down on the top of the spring 283 (Fig. 26). The opening 288 is accurately aligned with the adjustment block which happens to be in use at the moment, so that by screwing in the tool 287 the adjustment block is micrometrically adjusted along the groove 281 toward the center of the cam 259, and the segment of the cam in use is thus increased in thickness.

As previously described, the tuned circuit assembly 34 of the oscillator 62 (Fig. 1) has been fairly well aligned with the top and bottom dial readings by slipping the assembly, and by adjustment of the outside iron slug 15, and is ready for the final alignment. Standard frequency signals on all even megacycles are applied simultaneously at the input of the set. No confusion can exist between these various signals since we have lined up with the top and bottom one, and the range of frequency adjustment provided by adjustment of a block 279 is only about one-tenth the tuning range necessary to tune over one megacycle.

The inner dial 255 is set at zero, and the outer dial 271 is rotated to bring the thinnest sector of the cam 259 into use. Tool 287 is then screwed in, forcing down the adjustment block 279 until zero beat adjustment is achieved. Tool 287 is then retracted several turns, and the next thicker sector of the cam is brought into effective position. The process is repeated until all twenty-five faces of the cam have been lined up. Since standard signals, accurate to one part in a mil-

lion, are readily available, it is found that the adjustment of these blocks can be achieved to an accuracy of that order, or to a thickness adjustment accurate to one-millionth of an inch. The adjustment having been completed, tool **287** is screwed out, and a threaded plug **288***a* (Figure 5) inserted in its place to restore the housing **79** to a dust-tight condition.

It is always found desirable in using a scale of great length and precision to line up the apparatus related to that scale to an extremely high order of accuracy at a number of places throughout its range, rather than just at the top and bottom of the scale, or somewhere in the center. It is particularly important in a decade type of dial as shown that the discrete points set on the outer dial **271** be of very great accuracy, since a relatively small percentage of inaccuracy in the large steps of any decade device shows up as a large error in the lower steps of the decade. Any slight errors in the tuning curve of the tuned circuit assembly **34** (Fig. 1) is thus reduced by a large factor by this precise alignment of twenty-five distinct points.

If slightly greater inaccuracies are encountered in the tuning curve of the assembly **34**, these errors can be minimized by aligning the set on half, instead of whole, megacycles, with the inner dial **255**, of course, set at midpoint. The maximum error incident to lead screw operation will be just one-half as great when the range of such operation is distributed equally at opposite sides of an aligned point as when the range of such operation is all located at one side of the aligned point.

The transmitter of Fig. 2 is aligned in a slightly different manner than the receiver of Fig. 1. The untuned pickup coil **28** is at such a distance from the oscillator assembly **44** that one to three volts are picked up for exciting the buffer tube **63**, if great stability of the oscillator be desired. A detector and source of standard frequency are associated with the transmission line output shown. The oscillator is set at mid-point frequency and output tuned circuit **9** is adjusted by slipping to give maximum output at this frequency. The oscillator is then aligned as described in connection with the receiver by slipping, by adjusting the slug **15**, and finally by adjusting the thickness adjustment blocks of the dial mechanism. The oscillator is aligned at signal frequency, and not at some frequency differing therefrom by a fixed amount, as is necessary in a super-heterodyne type of receiver.

I have described what I believe to be the best example of practising my invention. I do not wish, however, to be confined to the example disclosed, but what I desire to cover by Letters Patent is set forth in the appended claims.

I claim:

1. The method of permanently lining up a unicontrolled core tuned radio receiver having directly coupled oscillator and mixer circuits, and an antenna circuit, each of which circuits includes a tuning coil, and a tuning core disposed within the coil and axially movable with respect thereto, said cores connected for operation in unison with one another and in common with an indicator dial, which comprises setting the dial to indicate a predetermined frequency while positioning the cores as an incident of such setting, connecting the mixer tube to act as a detector, providing a signal of such predetermined frequency then individually adjusting the positions of the mixer and antenna coils relative to the positioned cores of the mixer circuit and of the antenna circuit to produce resonance of the mixer and antenna circuits with said signal of the frequency indicated by the dial, while utilizing the energy output of said circuits as an aid in securing resonance, locking the mixer and antenna coils in the selected positions, reconnecting the mixer tube as a mixer, adjusting the position of the oscillator coil relative to the positioned oscillator core and the locked up mixer coil to adjust the oscillator frequency into a predetermined relation with the said frequency indicated by the dial, while utilizing the energy output of said oscillator circuit as an aid in securing such relationship, and locking the oscillator coil in the selected position.

2. The method of permanently lining up a unicontrolled core tuned radio receiver having directly coupled oscillator and mixer circuits, and an antenna circuit, each of which circuits includes a tuning coil and a tuning core disposed within the coil and axially movable with respect thereto, said cores connected for operation in unison with one another and in common with an indicator dial, which comprises setting the dial to indicate a predetermined frequency while positioning the cores as an incident of such setting, connecting the mixer tube to act as a detector, providing a signal of such predetermined frequency then individually adjusting the positions of the mixer and antenna coils relative to the positioned cores of the mixer circuit and of the antenna circuit and independently of the dial to produce resonance of the mixer and antenna circuits with said signal of the frequency indicated by the dial, while utilizing the energy output of said circuits as an aid in securing resonance locking the mixer and antenna coils up in the selected positions, reconnecting the mixer tube as a mixer, adjusting the position of the oscillator coil relative to the positioned oscillator core and independently of the dial to adjust the oscillator circuit frequency into a predetermined relation with the frequency of said signal of the frequency indicated by the dial, while utilizing the energy output of said oscillator circuit as an aid in securing such relationship, locking the oscillator coil in the selected position, and finally setting the dial successively to indicate each of a multiplicity of additional frequencies, and for each of such dial setting providing a signal of the frequency indicated by the dial and micrometrically adjusting the cores in unison relative to their associated coils and relative to the dial while utilizing the energy output of said circuits as desired in securing resonance, to establish a predetermined uniform relation of the oscillator frequency with the dial reading at the several selected frequencies.

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