Jan. 23, 1945. E. KARPLUS ET AL 2,367,681

ULTRA-HIGH-FREQUENCY TUNING APPARATUS

Filed Dec. 10, 1941 2 Sheets-Sheet 1

Fig. 1

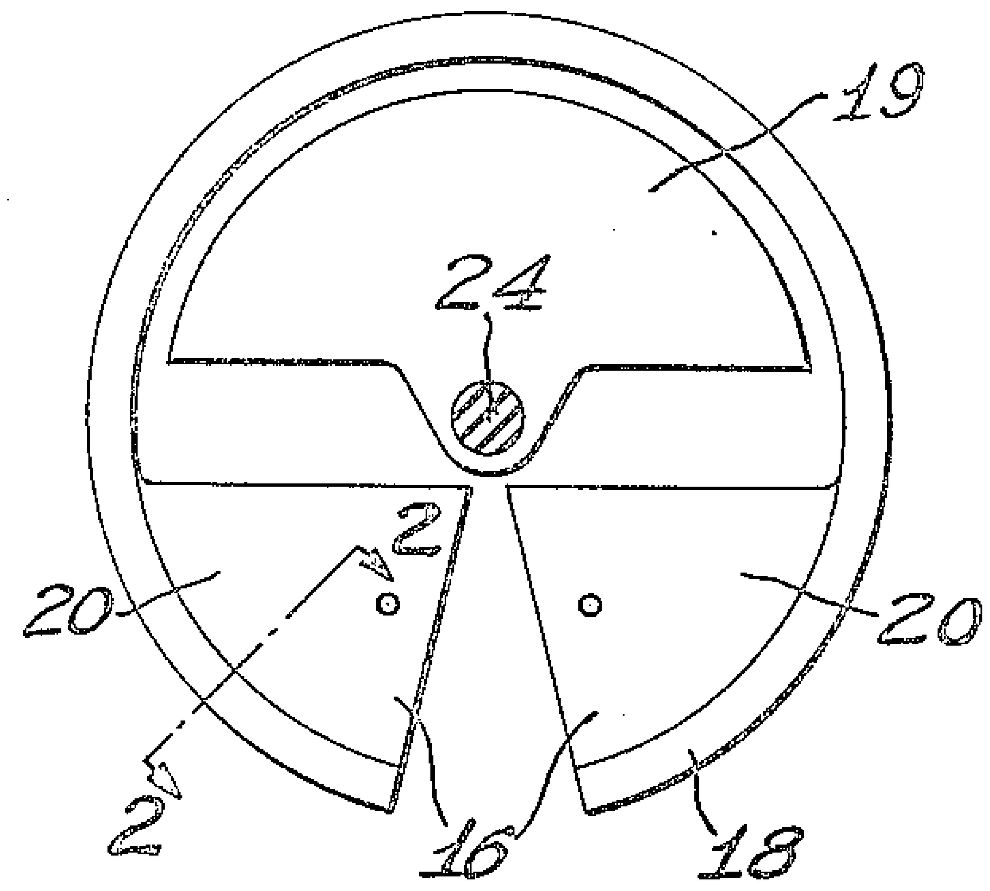


Fig. 2

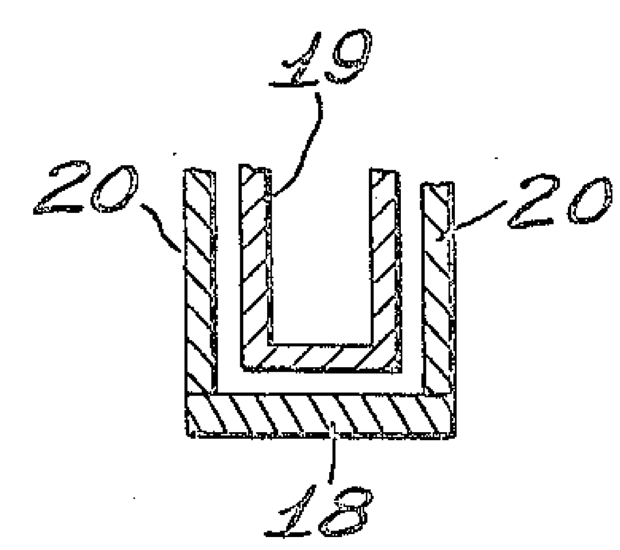


Fig. 3

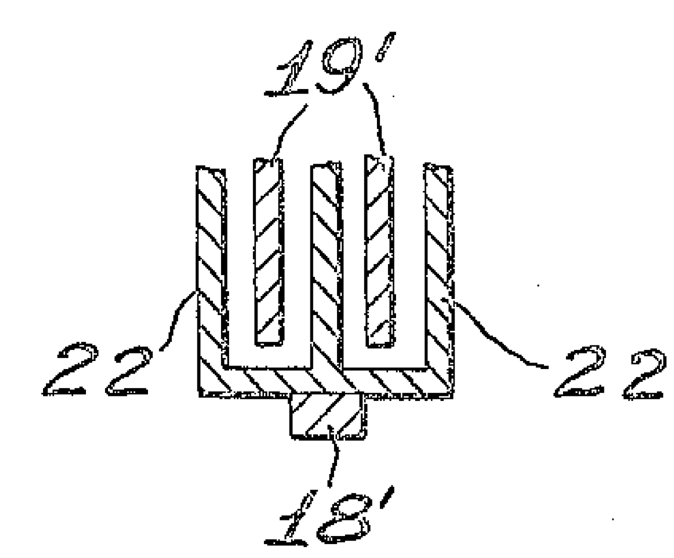


Fig. 4

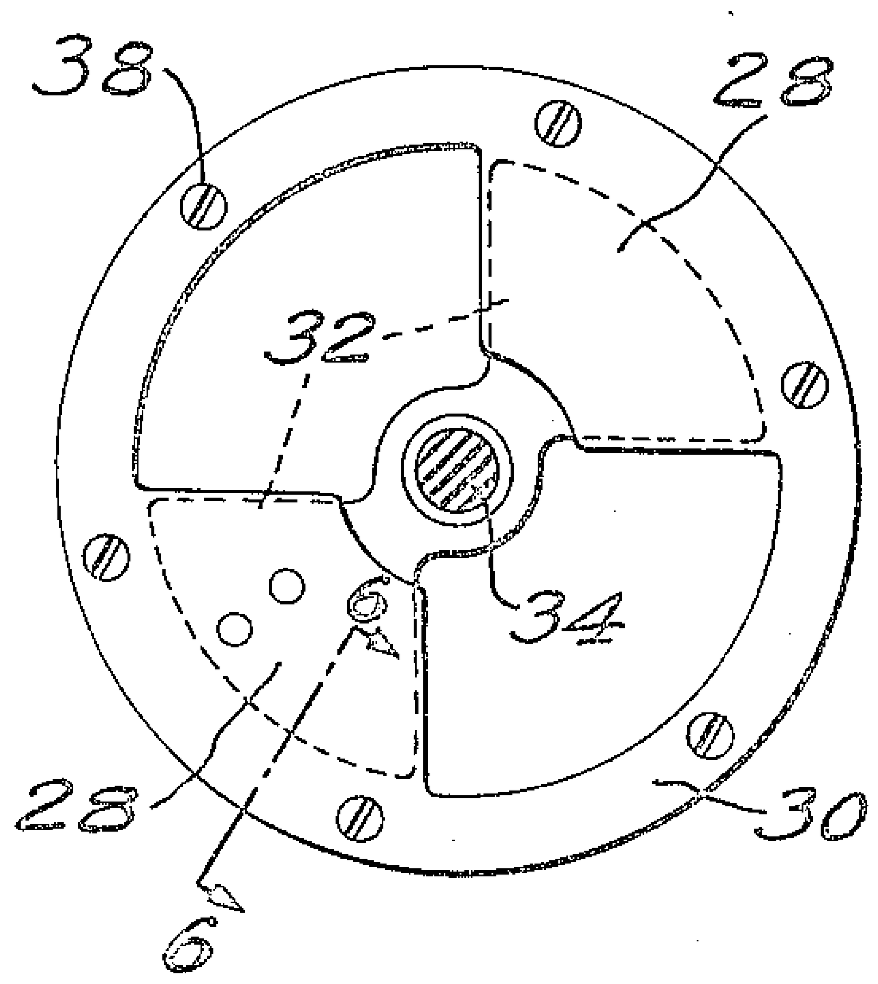


Fig. 5

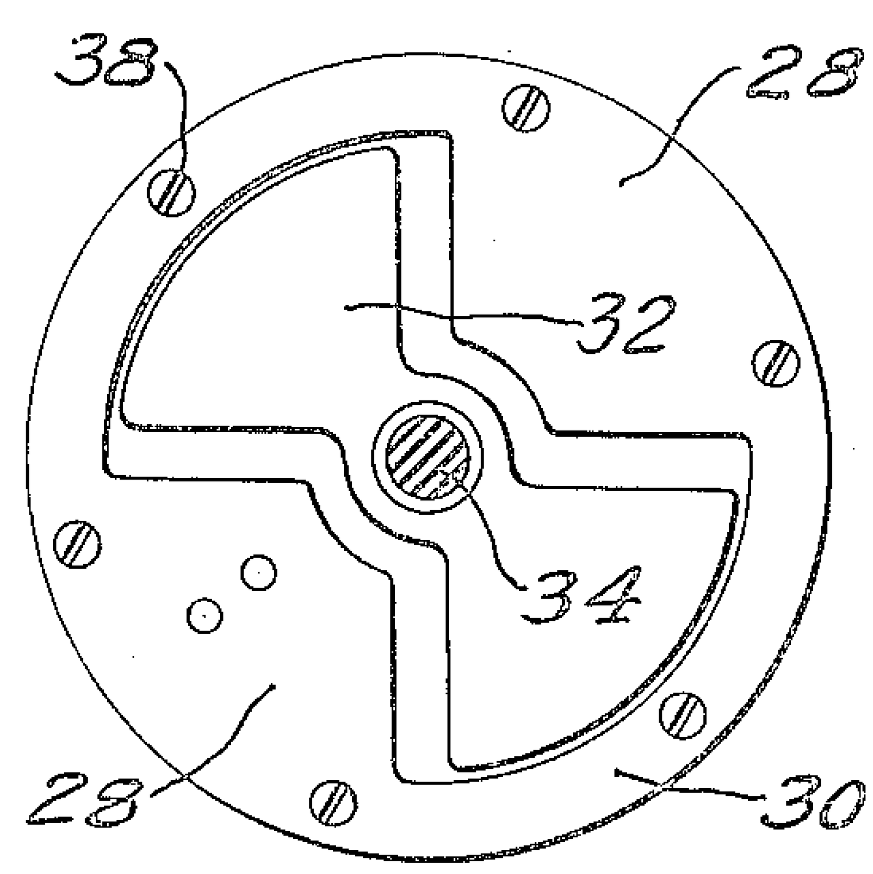


Fig. 6

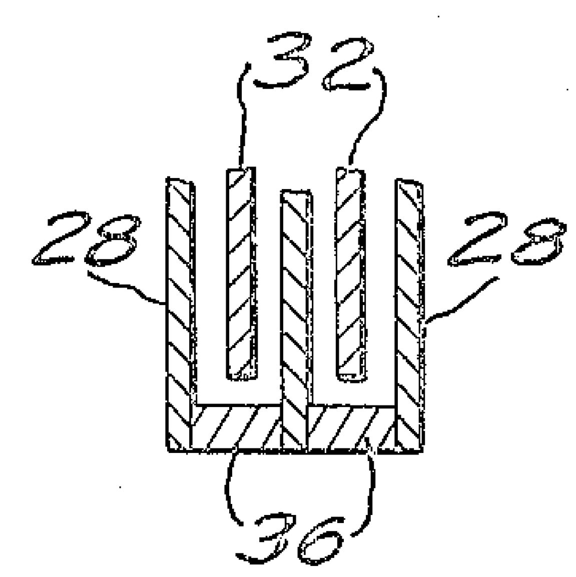


Fig. 7

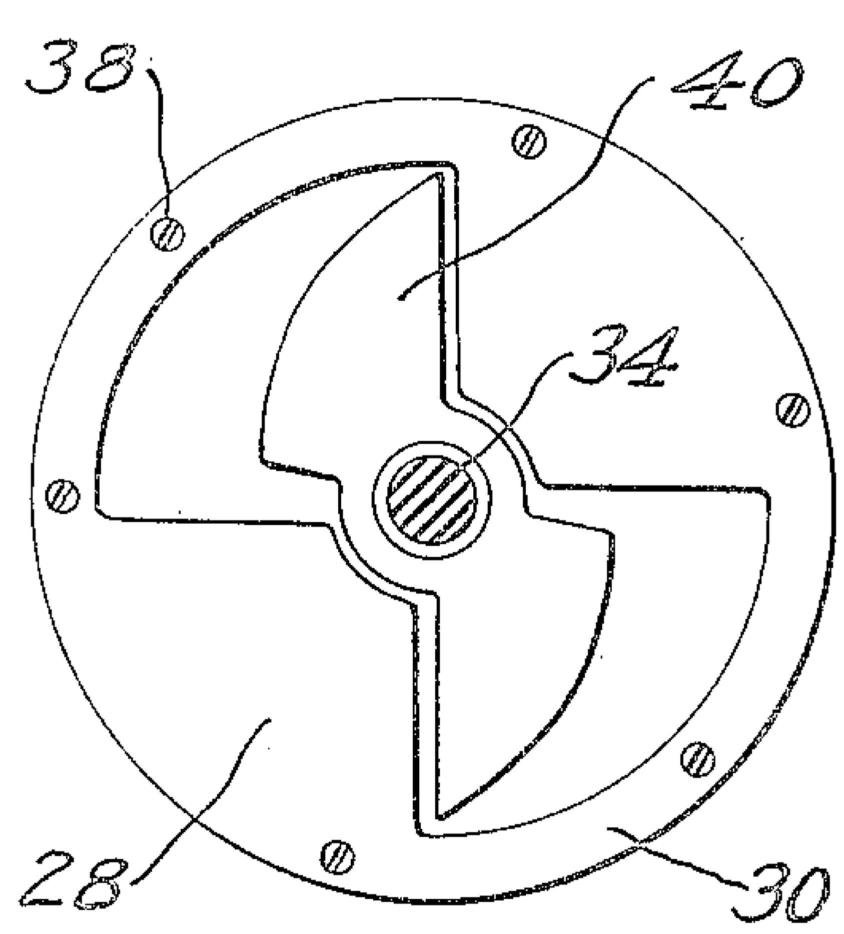
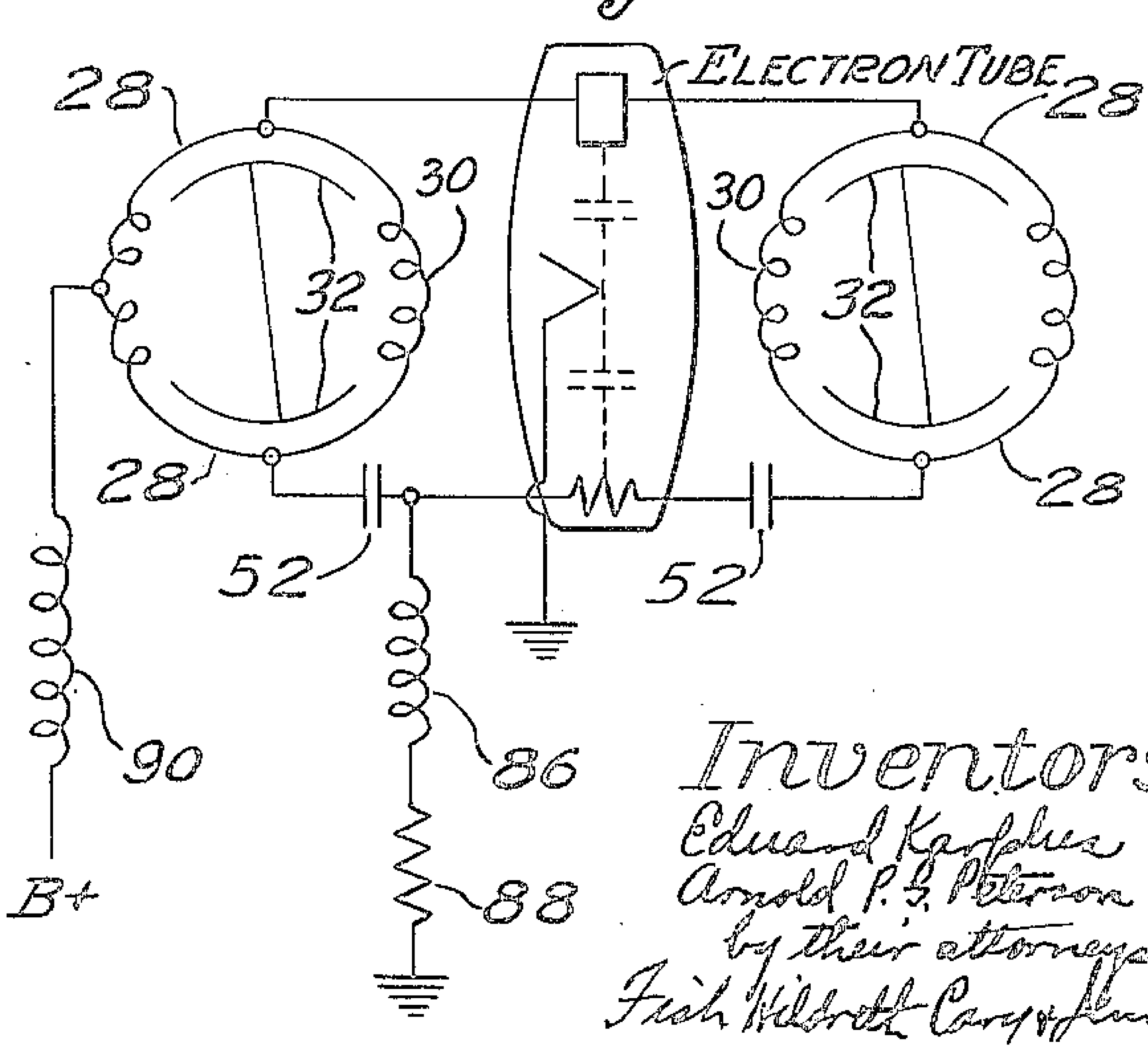


Fig. 11



Witness
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ULTRA-HIGH-FREQUENCY TUNING APPARATUS

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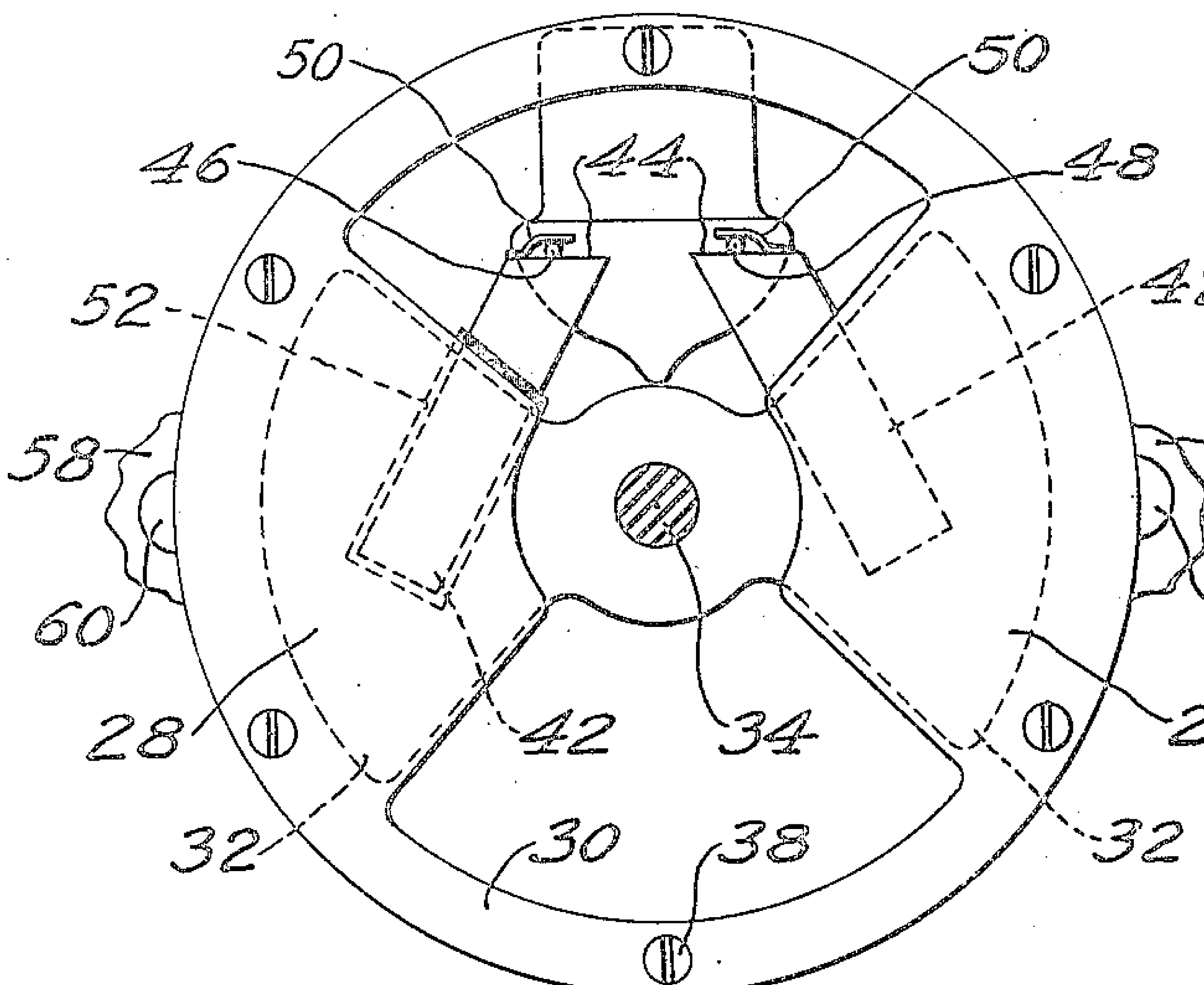

Fig. 8

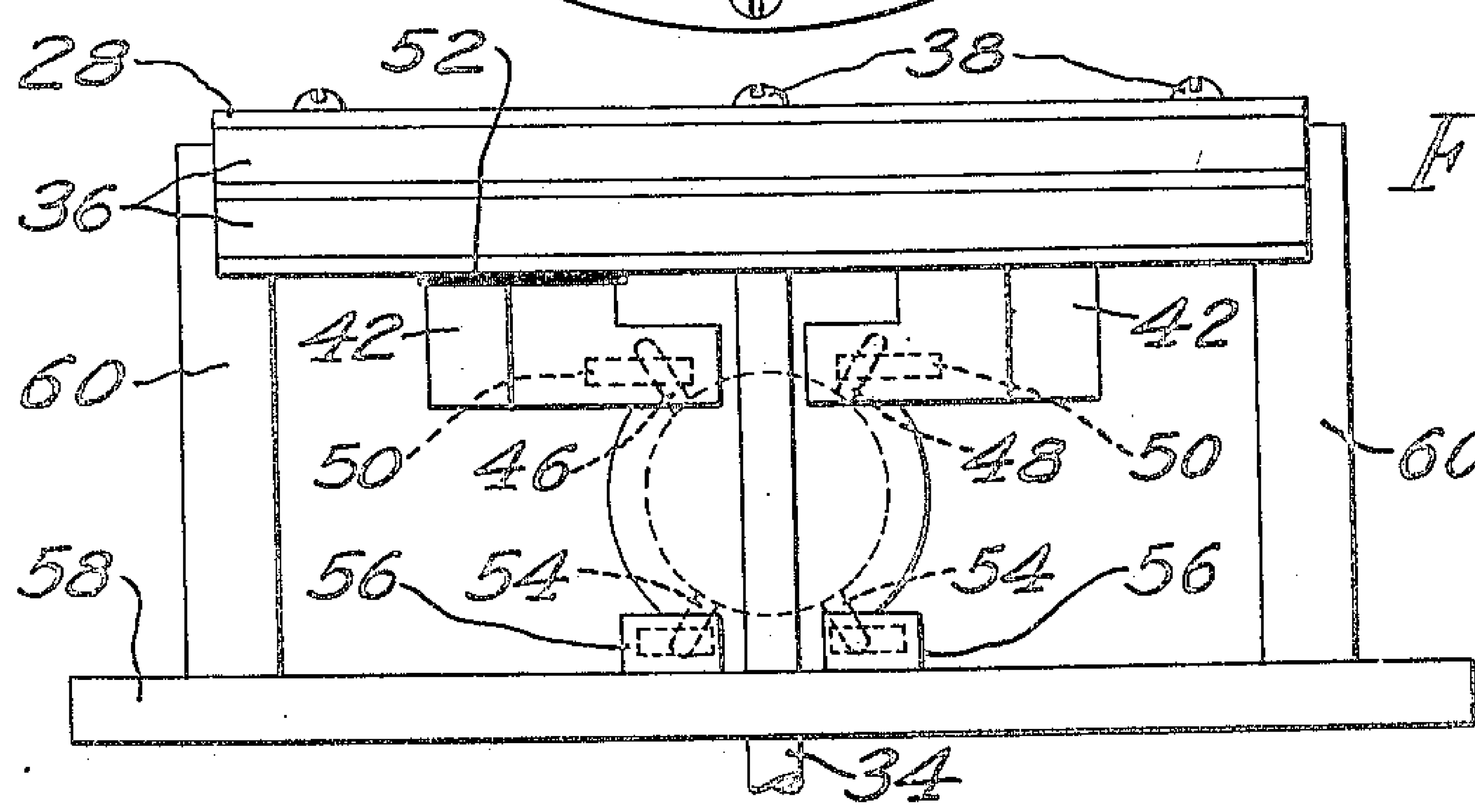

Fig. 9

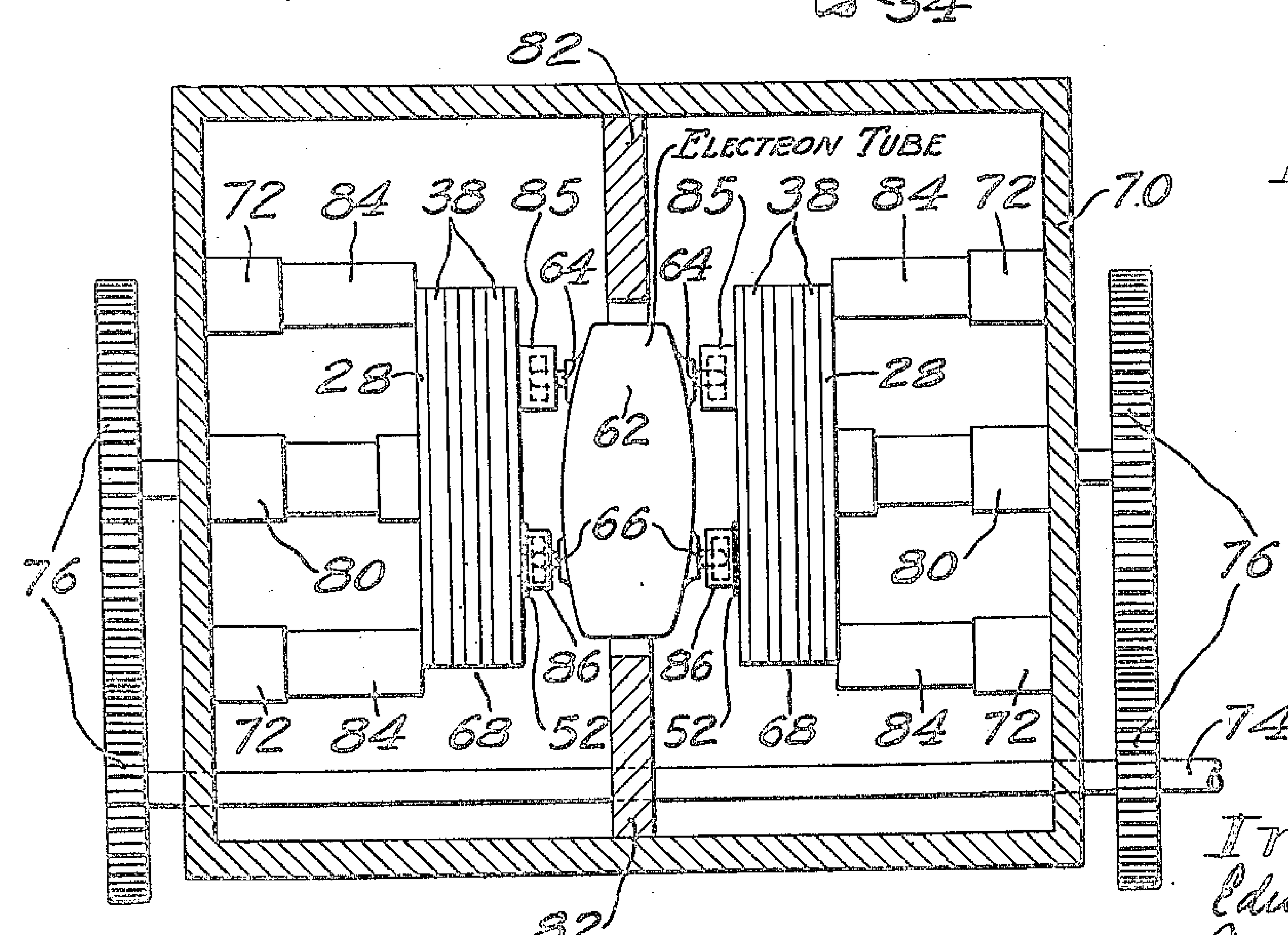

Fig. 10

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UNITED STATES PATENT OFFICE

2,367,681

ULTRA-HIGH-FREQUENCY TUNING APPARATUS

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Application December 10, 1941, Serial No. 422,348

9 Claims. (Cl. 250—40)

The present invention relates to ultra-high-frequency tuning apparatus.

The principal object of the present invention is to provide ultra-high-frequency tuning apparatus which is readily tunable over a wide frequency range, and which avoids the difficulties of erratic operation encountered in some existing resonant circuit controls.

With this and other objects in view, the present invention comprises the apparatus hereinafter described and particularly defined in the claims.

In the accompanying drawings, Fig. 1 is an elevation of one form of unit according to the present invention; Fig. 2 is a sectional detail view on line 2—2 of Fig. 1; Fig. 3 is a detail view similar to Fig. 2 but showing elements in different proportions; Figs. 4 and 5 are elevations of a modified form of apparatus; Fig. 6 is a sectional detail view on line 6—6 of Fig. 4; Fig. 7 is an elevation of a modification; Figs. 8 and 9 are views illustrating the use of a tuning unit with an oscillator tube; Fig. 10 is a sectional view showing two tuning units used with a tube; and Fig. 11 is a diagram of the circuit for the apparatus of Fig. 10.

The construction shown in Fig. 1 comprises a complete tuning unit suitable for use with an ultra-high-frequency oscillator. It includes simultaneously variable capacitive and inductive elements. The unit comprises two stator members **16**, each generally in the shape of a quadrant. The two stators are mechanically supported by an annular band **18**, to which the stator plates are soldered. The band may be considered as constituting the inductive element of the unit. A rotor element **19** is in capacitive relation to the stators.

The frequency range for which the unit is used is determined by the size of the band **18** and the number and size of the condenser plates **16**. For an extremely high frequency range, the arrangement shown in Fig. 2 may be used, wherein each stator comprises two plates **20** and the band **18** is relatively deep, whereby the unit has small capacitance and inductance. The rotor element **19** is constructed either as a solid or hollow assembly having only slight clearance with the stator plates.

For a lower frequency range, the construction shown in Fig. 3 may be used, wherein the stator is made up of a larger number of plates **22** to give higher capacitance, and the connecting band, shown at **18′**, is considerably narrower to increase the inductance. The rotor, here shown at **19′**, has a series of stacked plates adapted to interleave with the plates of the stators **16**.

In either form, the rotor is mounted on a shaft **24**, which is preferably of insulating material. The rotor is concentric with the band **18** and arranged so that its outer edge has only slight clearance with respect to the inside of the band. The rotor is adjustable from the position of Fig. 1 through an angle of 180° to a position in which the rotor is interleaved to the maximum extent with the stator elements.

The unit may be viewed as involving two condensers in series (each condenser including one of the stators and the rotor) and the inductance formed by the band **18**, said inductance being parallel with the series condensers. Actually the electric and magnetic field distributions are very complex, particularly for intermediate positions of the rotor, but the foregoing will serve for an explanation of the operation of the device. In the closed position, wherein the rotor is completely interleaved with the stator plates, both the capacitance and the inductance are at a maximum. In the position of Fig. 1, which may be termed "open" position, the inductance and the capacitance are at a minimum. The reduction in inductance is effected by the restriction of area for the passage of magnetic flux within the band **18**. It will be understood that at ultra-high-frequencies, the magnetic flux will pass through only the space not occupied by the metal rotor. For open and partially open positions, therefore, the flux will be constrained to pass through the restricted clearance space between the band **18** and the rotor, and the inductance will be markedly less than in the closed position of the rotor.

The simultaneous variation of both capacitance and inductance affords a wide tuning range. Moreover, this variation is attained without the use of sliding contacts or other connections to moving parts. Such connections have been a source of erratic operation in high-frequency resonant circuits. For example, when the rotor shaft is used as a current conducting element, the passage of stray currents through the metallic bearing surfaces may cause erratic operation. In the present invention, the rotor shaft may be of insulating material, so that the rotor may be said to float, and the bearings may be placed well outside the field, since their only function is to provide mechanical support for the rotor.

Figs. 4, 5 and 6 show a modified form of the invention in which opposed stator members **28** of quadrantal form are connected by inductive band elements **30**. A rotor assembly **32**, having opposed plates of generally sector shape, is mounted on a shaft **34**, concentric with the bands **30**. The stator may be constructed as shown in Figs. 2 and 3, by soldering of plates to the band, but a modified arrangement is shown in Fig. 6, whereby the stationary member is built up of died-out plates of proper shape with intermediate annular spacers **36**, the several plates and spacers being secured by screws **38**.

The construction of the above-described modification is symmetrical. Electrically, it is essentially the same as the construction of Fig. 1, except that two parallel inductive paths are connected between the stator elements. As in Fig. 1, both the inductance and capacitance are varied from minimum (Fig. 4) to maximum (Fig. 5) by movement of the rotor. The entire range in this case is covered by a rotor adjustment of 90°. The symmetrical construction is usually to be preferred over the construction of Fig. 1, because it can be constructed with greater mechanical rigidity; also, it results in smaller stray fields.

In Fig. 7 is shown a modification of the construction last described, wherein the rotor plates are shaped as indicated at **40** instead of having a circular periphery. The purpose of this shaping is to produce a desired relationship between tuning frequency and angle of variation. For example, in the unit of Fig. 4, the curve of the logarithm of frequency plotted against angle of rotor movement is approximately a straight line. This particular characteristic is desirable in standard-frequency oscillators. Substantially any desired characteristic may be obtained by proper shaping of the plates. It will be understood, however, that any departure of the rotor plates from true circular form results in a diminished inductive and capacitive variation, and hence in a diminished tuning range.

The devices heretofore described may be used wherever a variable resonant circuit is required, for example, in an absorption type wavemeter. They also find frequent use in conjunction with thermionic tubes, as oscillators, etc. In such cases, the tube elements (grid and plate) are preferably connected to the maximum potential points of the circuits, namely, to the stator elements. Such connections should be as short and direct as possible, to reduce the lead inductances between the tube elements and the high-potential points of the resonant circuits. The actual mounting arrangement for the tube will depend on the tube design. Two different tube mountings are shown in Figs. 8 to 10.

An arrangement involving the use of the tuning element with a so-called acorn type tube is shown in Figs. 8 and 9. Mounting brackets **42** are attached to the opposed stators **28**, and terminate in ledges **44** to support the grid and plate prongs **46** and **48** of the tube. The tube prongs are held in position by spring clips **50**. Since the brackets **42** are both at the same potential, so far as direct current is concerned, it is necessary to insulate the grid and plate prongs from each other. This is conveniently accomplished by means of a piece of mica or other insulating material **52** placed under one of the brackets **42**. At the high frequencies for which the unit is tuned, the insulation **52** introduces no more than a negligible impedance.

The cathode terminals **54** are mounted on suitable blocks **56** on the control panel **58**, through which the shaft **34** passes. The tuning assembly is mounted on the panel by means of supporting posts **60** preferably of insulating material.

In Fig. 10 is shown another arrangement employing an oscillator tube of different type. The tube is shown at **62**, and is provided with plate terminals **64** protruding from both sides and grid terminals **66** also protruding from both sides. This type of tube, when used in an ultra-high-frequency system, has usually been placed at the center of a half-wave transmission line made up of concentric or spaced parallel conductors. The transmission line forms an efficient circuit, but does not lend itself to adjustment. According to the present invention, the tube is connected in a circuit employing one or two of the tuning units previously described. As shown in Fig. 10, the tube is placed between two tuning units **68**, each of the type shown in Fig. 4, mounted in a metal enclosure **70** by means of supporting columns **72**. The rotor elements are adjusted simultaneously by means of a manually operated shaft **74** connected through gears **76** at both ends with the shafts **80** of the separate units. It has been found necessary to shield the tuning units **68** from each other, and this is accomplished by means of a metal shield **82** having an opening of proper size to receive the tube. Insulating spacers **84** are provided in the supporting columns **72** and the shafts **80**.

The plate terminals of the tube are directly connected to the tuning units by mounting blocks **85**, and the grid terminals are supported on mounting blocks **86** insulated from the tuning units by pieces of mica in the same manner as indicated at **52** in Fig. 8. For simplicity, the cathode connections are omitted from Fig. 10.

The electrical circuit for the system of Fig. 10 is shown in Fig. 11. The condenser stators are diagrammatically indicated at **28** and the rotors at **32**. The inductance elements **30** are indicated in the conventional way by coils **30**. The diagram is intended to indicate that variation of the rotor setting changes both the inductance and capacitance. The plate of the tube is connected through its opposed terminals to the stators **28** of the two units, and the grid is shown as connected to the symmetrically opposed stators through fixed condensers indicated at **52**. The grid is connected through a choke **86** and resistor **88** to ground. The plate supply is connected through chokes **90** with the mid-points of the inductance elements **30**. These mid-points are nodal or zero-potential points when the rotors are in fully open or fully closed position. At other rotor positions, the nodes may shift slightly, so that the chokes may be necessary to confine the high-frequency currents to the resonant circuit. The cathode of the tube is connected to ground. The internal capacitances of the tube are indicated in dotted lines. The system oscillates at a frequency dependent on the rotor setting. The feed-back coupling necessary for oscillation is furnished by the inter-electrode capacitances of the tube.

The system shown in Figs. 10 and 11 is bilateral, in that it affords symmetrical connections for the tube terminals. A uni-lateral system may be used by omitting one of the tuning units, but the bi-lateral arrangement, as shown in the drawings, is preferable because the inter-electrode capacitances are divided between the two resonant circuits, whereby a higher tuned frequency may be reached.

The diagram of Fig. 11, although directly applicable to the apparatus of Fig. 10, will serve to indicate an electrical circuit suitable for use in conjunction with any of the units herein described.

The invention is useful for ultra-high-frequency applications, for example, in circuits resonant to frequencies extending roughly from 30 to over 1000 megacycles per second.

It is to be understood that the invention is not limited to the precise embodiments herein described, but may be varied within the scope of the appended claims. For example, in some instances it has been found that supporting posts of metal may be used, particularly when the posts are long and the inductive loop is small. In such a case the posts provide a parallel inductive path, but at very high frequencies the inductance may be so high as to have a negligible effect.

The resonant circuit may be connected with a tube to form an oscillator in ways other than those shown. Instead of grounding the cathode, either plate or grid of the tube can be placed at ground potential for radio frequencies by grounding the corresponding part of the tuned circuit. Although the arrangement herein described with no electrical connections to the rotor is to be preferred, connections to the rotor may be made, if necessary or desirable, as for example, when the rotor is to be grounded or connected to a tube element. It will be understood that the relatively large circulating current in the resonant circuit would not be required to pass through the rotor connections, and the advantages heretofore noted would be obtained.

Having thus described our invention, we claim:

1. An ultra-high-frequency tuning unit comprising a pair of condenser stators of generally quadrantal shape, a complete annular band surrounding and supporting the stators and forming parallel inductive paths between them, and a rotor having quadrantal elements in capacitive relation to the stator and in inductive relation to the band and movable to vary both the capacitance and inductance of the unit.

2. An ultra-high-frequency tuning unit comprising a pair of condenser stators of generally sectorial shape, an annular band connecting and supporting the stators and forming parallel inductive paths, a rotor having elements in capacitive relation to the stator and in inductive relation to the band and movable to vary both the capacitance and inductance of the unit, and a shaft of insulating material for the rotor.

3. An ultra-high-frequency tuned circuit comprising a plurality of condenser stators, terminals on the stators, an inductive element connected to the separate stators and forming between them the inductive path of the tuned circuit, a movable element mounted for movement with respect to the stators and inductive element but not conductively connected therewith, the inductive element being disposed substantially in a plane and the movable element being movable in said plane, the movable element in closed position having a substantial surface opposed to the stator surfaces, and in open position substantially unopposed to the stator surfaces and in increased proximity to but out of contact with the inductive element to form with said inductive element a gap of reduced area for passage of magnetic flux, whereby the circuit may be varied from maximum capacitance and inductance between the terminals in closed position of the movable element to minimum capacitance and inductance between the terminals in open position of the movable element.

4. An ultra-high-frequency tuned circuit comprising a plurality of condenser stators, terminals on the stators, a looped inductive element connected to the separate stators and forming between them the inductive path of the tuned circuit, a rotor mounted for movement with respect to the stator and inductive element, the inductive element being disposed essentially in a plane and the rotor being movable about an axis perpendicular to said plane, the rotor in closed position having a substantial surface opposed to the stator surfaces, and in open position substantially unopposed to the stator surfaces and enclosed within but out of contact with the inductive element to form with said inductive element a gap of reduced area for passage of magnetic flux, whereby the circuit may be varied from maximum capacitance and inductance between the terminals in closed position to minimum capacitance and inductance between the terminals in open position of the rotor.

5. An ultra-high-frequency tuned circuit comprising a plurality of condenser stators, a band disposed essentially in a plane and connected to the separate stators and enclosing a free area, said band forming between the stators the inductive path of the tuned circuit, a movable element mounted for movement in said plane with respect to the stators and the inductive element between an open position and a closed position, the movable element having a substantial surface opposed to the stators in closed position and being substantially entirely included within said free area in open position, whereby the circuit may be varied from maximum capacitance and inductance in closed position to minimum capacitance and inductance in open position.

6. An ultra-high-frequency tuned circuit comprising a plurality of condenser stators, an annular band disposed essentially in a plane and connected to the separate stators and enclosing a free area, said band forming between the stators the inductive path of the tuned circuit, a rotor mounted for movement with respect to the stators and the inductive element about an axis perpendicular to said plane between an open position and a closed position, the rotor having a substantial surface opposed to the stators in closed position and being substantially entirely included within said free area in open position, whereby the circuit may be varied from maximum capacitance and inductance in closed position to minimum capacitance and inductance in open position.

7. An ultra-high-frequency tuned circuit comprising a pair of diametrically opposed stators of sectorial shape, an inductive element comprising an annular band disposed essentially in a plane and connected to the separate stators and enclosing a free area and forming between the stators the inductive path of the tuned circuit, a rotor having plates mounted to inter-leave with the stators for maximum inductance and capacitance and to lie within said free area for minimum inductance and capacitance, and means for mounting the rotor for adjustment about an axis perpendicular to said plane to either of said positions and other positions intermediate thereto.

8. An ultra-high-frequency tuned circuit comprising a plurality of condenser stators of generally sectorial shape, an inductive element comprising an annular band disposed essentially in a plane and connected to the separate stators and enclosing a free area and forming between the stators the inductive path of the tuned circuit, terminals on the stators, and a rotor having a portion movable about an axis perpendicular to said plane, between a closed position in which it has a large capacitive relation to the stators and an open position in which it occupies the free area

with reduced capacitance and inductance between terminals.

9. A variable circuit for providing a resonant ultra-high-frequency impedance comprising two terminals, a symmetrical pair of bands forming inductive paths between the terminals and providing a closed contour, a rotor movable within the contour between a position of maximum resonant frequency and a position of minimum resonant frequency, the bands being disposed essentially in a plane and the rotor being movable about an axis perpendicular to said plane, the rotor having extended portions providing substantial capacitance between the said terminals at the position of minimum resonant frequency and, by proximity to the inductive paths, reducing the inductance of the inductive paths at the position of maximum resonant frequency.

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