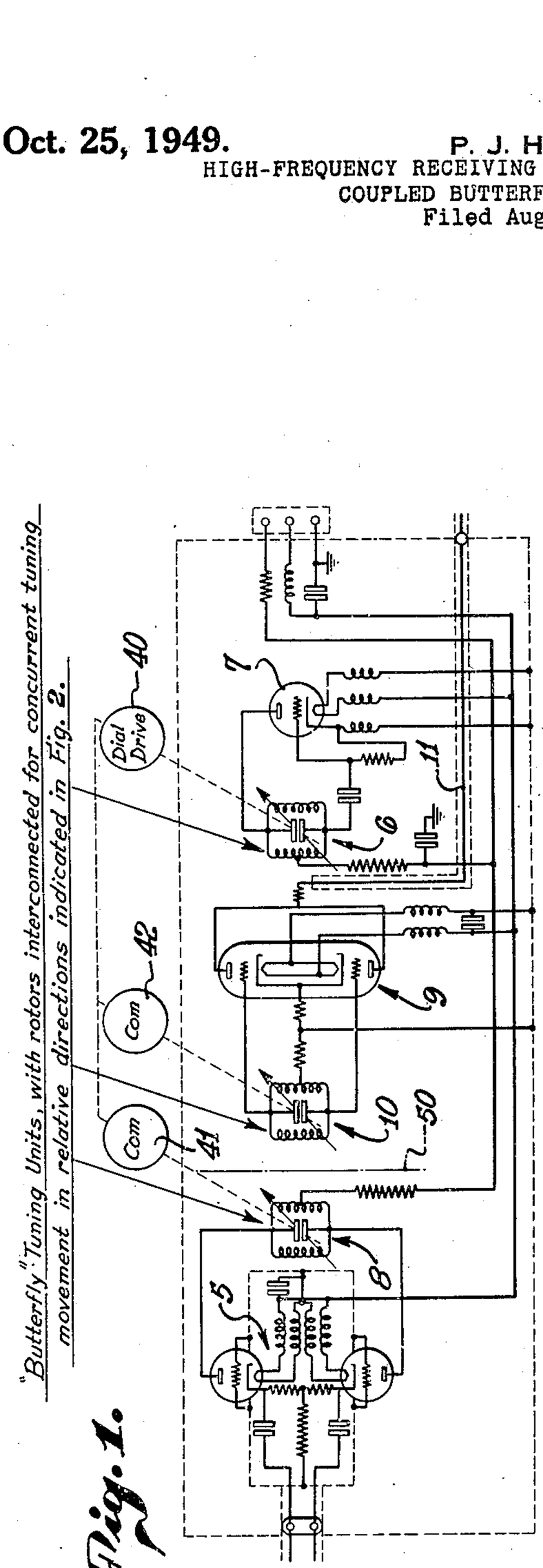
Oct. 25, 1949. P. J. HOLMES 2,485,884

HIGH-FREQUENCY RECEIVING SYSTEM HAVING INDUCTIVELY COUPLED BUTTERFLY TYPE CIRCUITS

Filed Aug. 29, 1945



"Butterfly" Tuning Units, with rotors interconnected for concurrent tuning movement in relative directions indicated in Fig. 2.

Fig. 1.

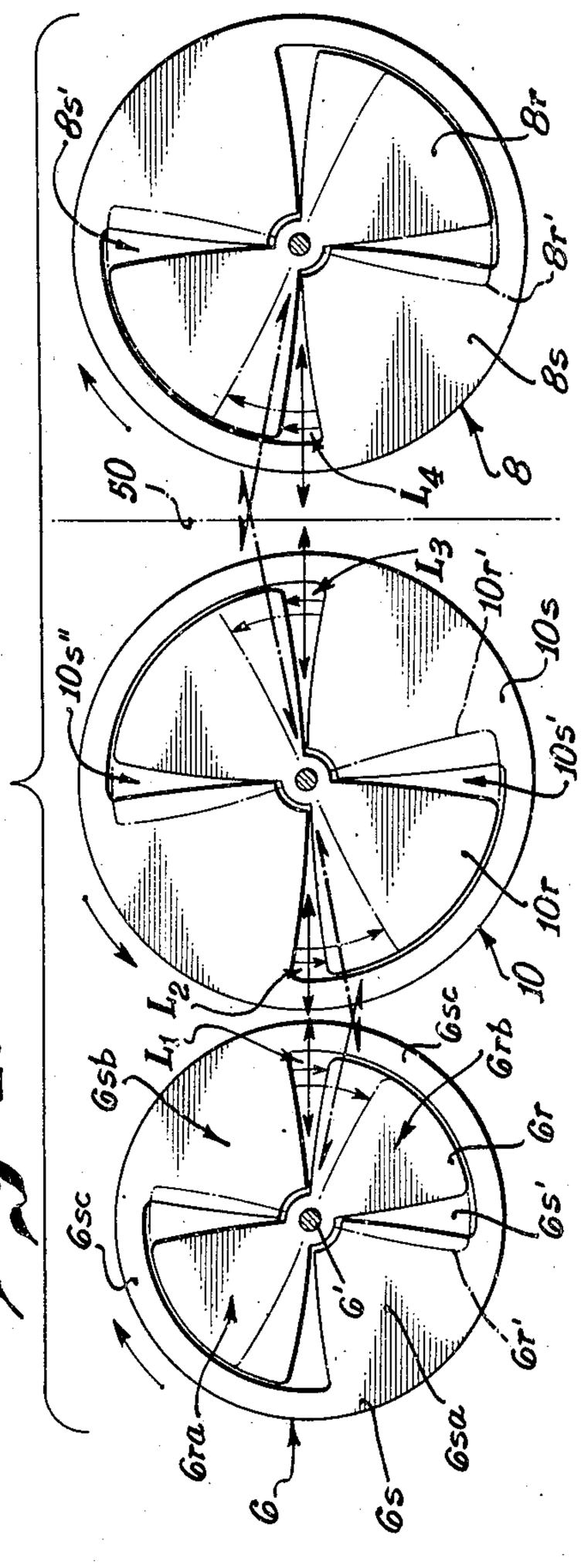


Fig. 2.

PAUL J. HOLMES,
INVENTOR.

BY Knight & Rodgers

ATTORNEYS

Patented Oct. 25, 1949

2,485,884

UNITED STATES PATENT OFFICE

2,485,884

HIGH-FREQUENCY RECEIVING SYSTEM HAVING INDUCTIVELY COUPLED BUTTERFLY TYPE CIRCUITS

Paul J. Holmes, Los Angeles, Calif., assignor to Richard R. Stoddart, Los Angeles, Calif.

Application August 29, 1945, Serial No. 613,321

2 Claims. (Cl. 250—40)

1

This invention relates to receiving systems adapted to respond to high frequency radio signals, more specifically, to signals in the so-called "ultra high frequency" range, and pertains particularly to means for interrelating the circuits of a plurality of electrically coupled tunable circuits of the "butterfly type" (hereinafter more particularly described), whereby the electrical coupling of the circuits is maintained at a substantially constant value throughout the tuning range of such circuits.

The expression "butterfly" as used herein, is an adoption of the term which has been applied by those skilled in the art to that type of high frequency tuning unit which comprises a pair of condensor stators of generally quadrantal shape, a complete annular band surrounding and supporting the stators and forming parallel inductive paths between the condenser stators, and a rotor having elements in capacitative relation to the stator and in inductive relation to the band and movable to vary both the capacitance and the inductance of the unit, all as more particularly described in U. S. Patent No. 2,367,681, issued Jan. 23, 1945, to General Radio Company, Cambridge, Mass. Further description of these "butterfly" units, and of the so-called "butterfly circuits" incorporating a pair of the units in inductively coupled relation, may be found in the October, 1944, issue of the "General Radio Experimenter" published by General Radio Company, aforesaid.

An important objective of the invention is to provide a plurality of tunable circuits which are inductively coupled to provide a desired interrelation, in which the resonant impedance of the several circuits is maintained at a substantially constant value over the tuning range of the circuits.

A further object of the invention is to provide, in a receiving system, with a plurality of the so-called "butterfly" circuits functioning as the tunable elements and each having substantially constant resonant impedance throughout the operating frequency range, in which inductive coupling is obtained between certain of of these tunable elements, and which provides a substantially constant coupling between said elements throughout the operating frequency range, whereby a high degree of uniformity of response to signal strength is secured throughout such frequency range.

A particular object of the invention is to provide, in a radio receiving system adapted for operation in the so-called "ultra" high frequency

2

range for the measurement of the strength of the received signal, a radio-frequency tuning unit having a substantially uniform response at all frequencies within the tunable range of the instrument, whereby the indicated signal strengths are in substantially constant proportion to the received signal strengths at all frequencies within such range.

A further particular object of the invention is to provide an ultra-high-frequency radio receiving instrument in which the received voltage is mixed with a reference voltage to produce an intermediate frequency signal which may be subjected to amplification for ultimate voltage measurement to provide an indication proportional to the value of the received voltage, in which tuned circuits of the "butterfly" type are employed to produce such intermediate frequency signal in such manner as to attain a nearly constant resonant impedance in such circuits over the tuning range of the instrument.

In general, the invention is directed to a very high frequency-ultra high frequency receiving system employing at least one pair of inductively coupled circuits of the "butterfly" type employing the so-called "butterfly" tuning units, which units are provided with rotor and stator plate assemblies which constitute a high resonant impedance device incorporating both inductance and capacitance which can simultaneously be changed by varying the mesh between the rotor and stator plates. For the purpose of simplicity of description, such tuning units are hereinafter referred to merely as "butterflies." The invention may comprise a pair of such butterflies arranged in inductive juxtaposition with the axes of the two rotor assemblies arranged in substantially parallel relation. The stators of the "butterflies" are disposed in a symmetrical arrangement such that open sectors thereof adjacent the inductive coupling position are disposed in adjacent positions at the same side of a line passing through the rotor axes, and the rotors are arranged so that the rotor plate portions are adapted to be disposed in a substantially symmetrical alinement with the respective open sectors of the stators in a minimum capacity tuned condition. The rotors are arranged for rotation in opposite rotative directions so as to cause such plate portions to move in the same direction away from said line and toward said same side of said line, in tuning to a higher capacity condition.

In its preferred application the invention contemplates the use of three "butterflies," arranged with their rotor axes in a generally parallel relation in a substantially common plane, with the first and second butterflies arranged in inductive juxtapasition to define an inductively coupled pair and the second and third butterflies arranged in inductive juxtaposition to define a second inductively coupled pair. The stators and rotor plate portions of the first pair may be arranged and relatively rotated as described in the preceding paragraph, and the stators and rotors of the second pair may be arranged in a relatively opposite relation as compared to that of the first pair, with respect to the common plane of the rotor axes.

In general, the rotors of the several butterflies are preferably interconnected for concurrent rotation in the proper relative directions, and for correction of misalignment at various tuned conditions of the rotors, and at least one of the butterflies will be positionally adjustable with respect to the adjacent butterfly, in which case I preferably provide a coupling shield between such adjacent butterflies to prevent overcoupling and minimize mutual capacity shift between such butterflies as the rotor plates are shifted out of symmetrical position as a result of the positional adjustment of one butterfly. Other features and objects of the invention will be specifically recited in or will be apparent from the ensuing specific description.

As a specific example of the application of this invention to the ultra high frequency art, the accompanying drawings illustrate a radio frequency amplifying and mixing circuit embodying inductively coupled butterflies in accordance with the invention, especially adapted for use in a field strength and noise meter, and referring thereto:

Fig. 1 illustrates a schematic circuit diagram of such specific application; and

Fig. 2 illustrates an arrangement of the stator and rotor plates of interrelated butterflies employed in the circuit of Fig. 1.

The amplifying and mixing circuit illustrated in Fig. 1 comprises the R. F. amplifier stage **5**, which may be of the grounded grid type provided with two type 6J4 tubes in push-pull for operation with a balanced transmission line. The push-pull plates of the amplifier are connected to the "butterfly" tuned circuit, indicated at **8**.

The oscillator **7** may comprise a type 9002 triode connected in a conventional Colpitts circuit and employing a tuned "butterfly" circuit **6**. The oscillator **7** is adapted to operate at a frequency higher than the R. F. stage, say 30 mc., for example.

The mixer stage **9** may comprise a type 6J6 dual triode with the grids in push-pull and the plates in parallel; the grids being connected to a "butterfly" **10** which is inductively coupled to the butterflies **8** and **6** of the R. F. amplifier and the oscillator, respectively. The particular arrangement of the butterflies **6**, **8** and **10** is hereinafter more particularly described, in connection with the description of certain important objects of this invention.

The operation of the oscillator **7** at a 30 mc. higher frequency than the R. F. amplifier produces an I. F. in the mixer plate circuit of 30 mc. A relatively high frequency difference is selected in order to improve the image rejection in the mixer.

The I. F. signal from the mixer **9** is delivered from the circuit through a low capacity shielded line **11**.

The tunable butterfly circuits of the oscillator **6**, R. F. amplifier **8** and mixer **10** are interconnected for concurrent or ganged operation in proper rotative directions as described below in connection with Fig. 2; the oscillator butterfly **6** is preferably direct connected for operation by the dial drive **40**, while the R. F. and mixer butterflies are provided with compensators **41** and **42** for correction of tuning misalignment.

Referring to Fig. 2, the three butterfly elements **6**, **8** and **10** are shown in structural detail, to illustrate the preferred arrangement which I employ to secure the maximum performance from the equipment, wherein the butterfly elements are represented as comprising rotor and stator assemblies indicated by the exponents *r* and *s*, respectively, arranged with the rotor axes arranged in a generally parallel relation in a substantially common plane. Each of the butterfly tuning units may be formed of a stator assembly **6***s* (taking the element **6** for example), having two symmetrically opposed stator members **6***sa* and **6***sb* of generally quadrantal shape connected by inductive band elements **6***cs*, and a rotor assembly **6***r* having opposed plates **6***ra* and **6***rb* of generally sector shape and mounted on a shaft **6′** concentric with the band elements **6***sc* and rotatably adjustable with respect to the stator members **6***sa* and **6***sb*. The full line rotatively adjusted position of the units **6**, **8** and **10** in Fig. 2 is the minimum capacitance and minimum inductance (maximum frequency) condition, and both the capacitance and inductance are adjustable to maximum values (minimum frequency condition) by rotation of the rotor plate **6***ra* and **6***rb* into overlapping relation with the stator members **6***sa* and **6***sb*. A 90° rotation serves to adjust the unit from minimum to maximum value condition, and the direction of rotor rotation of each element required for attainment of the objects of this invention are indicated by directional arrows at the upper left edge of the respective elements for tuning to lower frequency. It will be noted that the angular extent of the individual stator members and rotor plates (such as **6***sa* and **6***sb*, **6***ra* and **6***rb*, for example) is somewhat less than 90°, and the angular extent of the open sectors **6***s′*, **8***s′* and **10***s′* between the stator members **6***s*, **8***s* and **10***s* is somewhat more than 90°. This provides useful coupling loops L1:L2 and L3:L4 even in the full line minimum capacitance condition, at the position of which the coupling of units **6**:**10** and **10**:**8** is established.

The useful coupling loop L_1 for the element **6** is considered to be at the "3 o'clock" position and that for the element **10** at the adjacent "9 o'clock" position, L_2, as between the elements **6** and **10**. As between the elements **10** and **8** (between the mixer and R. F. amplifier) the coupling loop L_3 for the element **10** is considered to be at the "3 o'clock" position and that for the element **8** at the adjacent "9 o'clock" position, L_4.

The stators **6***s* and **10***s* are arranged in such manner that the adjacent open sectors **6***s′* and **10***s′* are directed toward one another, i. e., the sector **6***s′* of the butterfly **6** is arranged in a 3 o'clock : 6 o'clock orientation, adjacent the sector **10***s′* of the butterfly **10** which is disposed in a 6 o'clock : 9 o'clock orientation whereby said open sectors are disposed in adjacent positions at the

same side (below, in Fig. 2) of a line passing through the axes of rotors 6*r* and 10*r*. Similarly, the stators 8*s* and 10*s* are arranged in such manner that the adjacent open sectors 8*s'* and 10*s''* are directed toward one another, i. e., the sector 8*s'* of the butterfly 8 is arranged in a 9 o'clock : 12 o'clock orientation, adjacent the sector 10*s''* of the butterfly 10 which is disposed in a 12 o'clock : 3 o'clock orientation whereby said open sectors 8*s'* and 10*s''* are disposed in adjacent positions at the same side (above, in Fig. 2) of a line passing through the axes of rotors 8*r* and 10*r*, but at the side thereof which is opposite the side at which the open sectors 6*s'* and 10*s'* are disposed. As the elements 6, 8 and 10 are tuned toward higher capacity : lower frequency condition, the stators are caused to rotate in such direction, respectively, that the centers of the loops L_1, L_2 and L_3, L_4 are constantly directed toward one another, as shown by the solid double-headed arrows for the full-line position of the stators and the dot-dash double-headed arrows for the dot-dash positions 6*r'*, 8*r'* and 10*r'* corresponding to a lower-frequency tuned condition. In the minimum capacity condition, the rotor plate portions are symmetrically alined with the respective stator open sectors, and in tuning to a higher capacity condition the rotors are caused to move so that the adjacent plate portions of each inductively coupled pair of butterflies move in the same direction away from the common plane of the axes, the first pair 6 and 10 having a rotor movement such as to carry the rotor plate portions downwardly in Fig. 2, and the second pair 10 and 8 having a rotor movement such as to carry the rotor plate portions upwardly in Fig. 2, opposite the common direction of movement of the rotor plate portions of the first pair.

Rotation of the rotors 6*r*, 8*r* and 10*r* in a clockwise, counter-clockwise and clockwise direction, respectively, will thus cause a minimum change in coupling between the butterfly pairs 6—10 and 8—10, in tuning from high-frequency to low-frequency condition, wherefore a high degree of uniformity is attained in the intermediate frequency mixed signal at the various frequencies within the tunable range of the device, for any given R. F. signal strength.

As brought out above, the oscillator 6 is preferably direct driven as at 40, and compensating drive means 41 and 42 are provided for the R. F. unit 8 and the mixing unit 10, so that the latter circuits may be "trimmed" or adjusted independent of the adjustment of the oscillator 6. According to a preferred embodiment of the invention, I preferably provide a shield plate between the butterflies 8 and 10, as indicated by the heavy dot-dash line 50 in Figs. 1 and 2, to reduce and substantially eliminate interaction between these butterflies during the trimming operation. Any interaction would seriously interfere with facile tuning, and the provision of a shield plate between 8 and 10 substantially eliminates this interaction, wherefore the trimming of the two butterflies 8 and 10 is caused to be substantially independent. If desired, this shield plate may be provided with an opening in line with the coupling loops L_3—L_4 in the high-frequency position of the rotors, to decrease its tendency to function as an electromagnetic shield and therefore decrease the tendency of the plate to reduce the coupling at high frequencies.

Modifications in the structure will occur to those skilled in the art, wherefore I do not choose to be limited to the precise details herein shown and described, but rather to the scope of the subjoined claims.

I claim:

1. In a very high frequency-ultra high frequency receiving system employing two inductively coupled circuits of the "butterfly" type, the combination which comprises: a pair of capacitance : inductance tuning units of the "butterfly" type each having a stator provided with opposed quadrantal stator sectors and intermediate quadrantally shaped open sectors, and a rotor provided with opposed plates, said units being arranged in inductive coupling juxtaposition with each other, with the axes of the rotors extending in a substantially parallel relation, said tuning units being disposed in symmetrical arrangement with open sectors of the respective stators in adjacent positions at the same side of a line passing through said axes, and with plates of the respective rotors disposed in symmetrical alinement with the respective adjacently disposed open sectors of said stators in a minimum capacity tuned condition, and said rotors being interconnected for concurrent rotative movement in opposite rotative directions so as to cause said last mentioned plates to move in the same direction away from said line and toward said side in tuning to a higher capacity condition.

2. In a very high frequency-ultra high frequency receiving system employing inductively coupled circuits of the "butterfly" type, the combination which comprises: three capacitance : inductance tuning units of the "butterfly" type each having a stator provided with opposed quadrantal stator sectors and intermediate quadrantally shaped open sectors, and a rotor provided with opposed plates, and arranged with their rotor axes extending in a substantially parallel relation in a substantially common plane; the first and second tuning units being disposed in inductive coupling juxtaposition with each other to define a first inductively coupled pair of tuning units, and the second and third tuning units being disposed in inductive coupling juxtaposition with each other to define a second inductively coupled pair of tuning units; the tuning units of said first pair being disposed in symmetrical arrangement, with open sectors of their respective stators in adjacent positions at the same side of said common plane and with adjacently disposed plates of their respective rotors disposed in symmetrical alinement with the respective adjacently disposed open sectors of said stators in a minimum capacity tuned condition; the tuning units of said second pair being disposed in symmetrical arrangement, with another open sector of the stator of said second tuning unit and an open sector of the stator of said third tuning unit in adjacent positions at the opposite side of said common plane, and with adjacently disposed plates of their respective rotors disposed in symmetrical alinement with the respective adjacently disposed open sectors of the stators of said second pair of tuning units in a minimum capacity tuned condition; and the rotors of each pair of tuning units being interconnected for concurrent rotative movement in opposite rotative directions so as to cause said adjacently disposed rotator plates of said first pair of tuning units to move in the same direction away from said common plane and toward said same side thereof, and to cause said adjacently disposed rotor plates of said second pair of tuning units to move in the same direction away

from said common plane and toward said opposite side thereof, in tuning said units to a higher capacity condition.

PAUL J. HOLMES.

REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,194,696	Eickemeyer et al.	Mar. 26, 1940
2,297,266	Vieweger	Sept. 29, 1942
2,341,345	Van Billiard	Feb. 8, 1944
2,367,681	Karplus et al.	Jan. 23, 1945
2,408,895	Turner	Oct. 8, 1946