

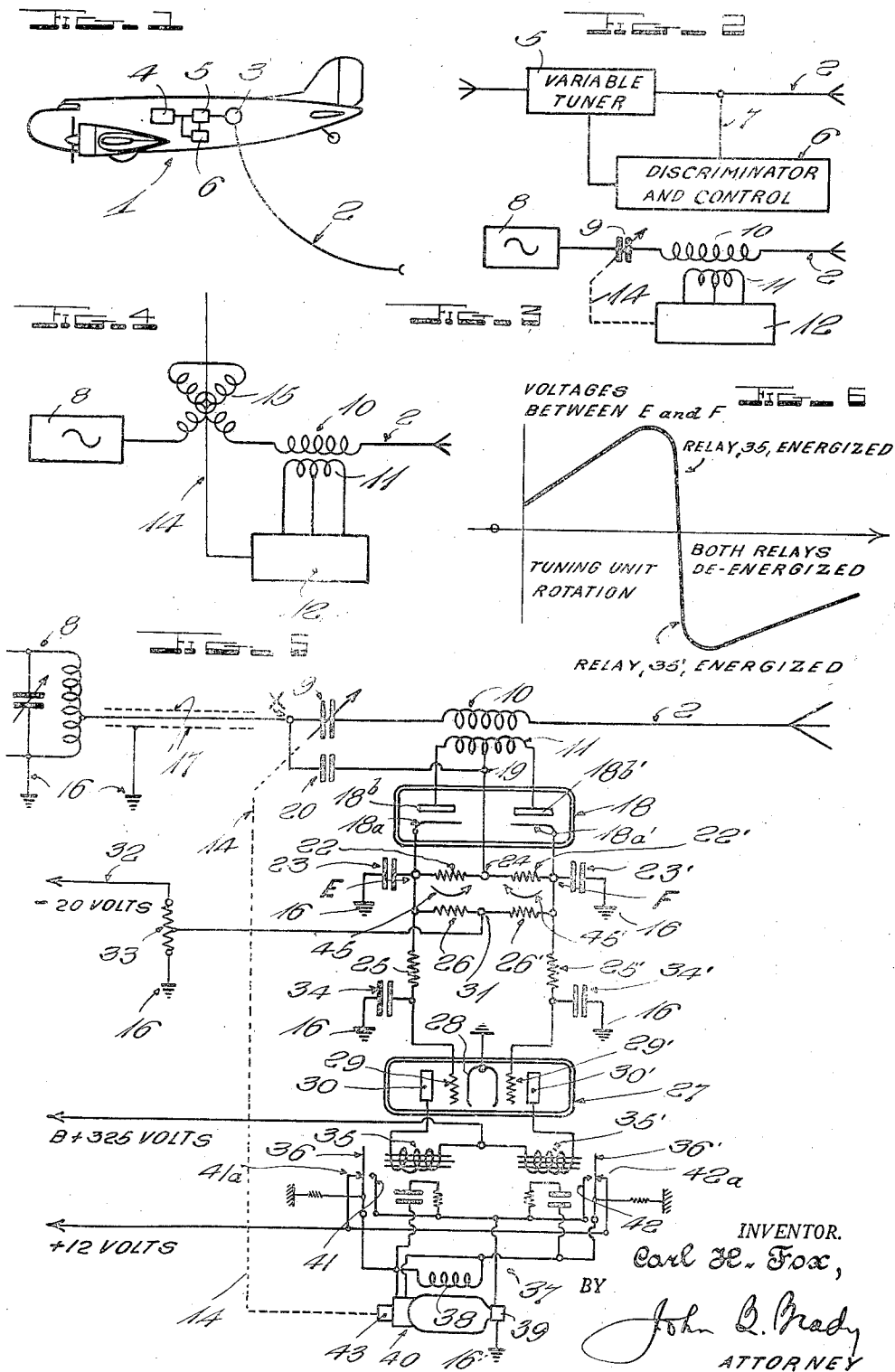
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AIRPLANE ANTENNA AUTOMATIC TUNING SYSTEM

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AIRPLANE ANTENNA AUTOMATIC
TUNING SYSTEM

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My invention relates broadly to radio transmission systems and more particularly to an automatic tuning system for radio transmission circuits.

One of the objects of my invention is to provide a circuit arrangement for automatically adjusting the periodicity of an electrical circuit under control of the energy supplied to the circuit.

Another object of my invention is to provide an automatic tuning means particularly adapted for adjusting the resonance of a circuit to a predetermined frequency under control of the energy supplied to the circuit.

Still another object of my invention is to provide an arrangement of electrical apparatus for automatically adjusting the tuning of an electrical circuit to the frequency of the energy impressed upon that circuit from a supply circuit.

A further object of my invention is to provide an attachment for aircraft radio transmitters by which the tuning of the aircraft radio antenna may be adjusted to resonance with the exciting frequency under conditions where the physical length of the antenna may be thereby inefficient for transmission at the frequency impressed upon the antenna by the transmitter.

Another object of my invention is to provide a construction of automatic tuning unit for aircraft antennae which automatically operates in the event that a portion of the antenna may be shot away, reeled in or otherwise disturbed for automatically tuning the remaining portion of the antenna to form an efficient radiator for energy impressed upon the antenna by the radio transmission.

Other and further objects of my invention reside in an arrangement of automatic tuning system for aircraft antennae for maintaining resonance of the antennae with the transmission frequency of the radio transmitter as set forth more fully in the specification hereinafter following by reference to the accompanying drawings in which Fig. 1 schematically illustrates the trailing wire antenna system of an aircraft which is automatically tuned by the unit of my invention; Fig. 2 schematically illustrates the principles of my invention in which a portion of the energy from the antenna is supplied to a discriminator and automatic tuning control circuit which controls the operation of a variable tuning device interposed in the antenna circuit; Fig. 3 schematically illustrates the control of the antenna periodicity by a capacitive adjustment system; Fig. 4 illustrates the control of the antenna

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periodicity by means of an inductive adjusting system; Fig. 5 is a diagrammatic circuit arrangement showing the automatic tuning system of my invention as applied to the trailing wire antenna of an aircraft; and Fig. 6 is a curve diagram illustrating the principles of operation of the control mechanism in the automatic tuning control circuit of my invention.

The unit will also adjust antenna or tuning circuit automatically to proper condition in case the frequency of the source of power is changed.

My invention is directed to an automatic system for electrically adjusting a high frequency circuit to resonance with the supply frequency.

There are many embodiments of the principles of my invention and while I have particularly disclosed my invention as applied to the trailing wire antenna of an aircraft radio transmitter, I desire that it be understood that my invention is also applicable to electrical circuits generally for adjusting the periodicity of such circuits to resonance with the supply frequency.

My invention meets the specialized problems encountered in aircraft operation of radio transmitters and provides means for automatically adjusting the antenna circuit to resonance with the frequency of the supply circuit. Where a portion of the antenna may be shot away rendering the antenna non-resonant with the transmission frequency the apparatus of my invention automatically retunes the antenna circuit for efficiently radiating the energy impressed thereon by the radio transmitter. I provide means for utilizing a small portion of the energy supplied to the trailing wire antenna for operating a differentially operated control circuit which operates an automatic tuning control. The automatic tuning control functions to control a variable tuning device in circuit with the antenna for readjusting the antenna to resonance with the supply frequency in the event that the antenna may be off-resonance with respect to the transmission frequency. I may employ either capacitive tuning or inductive tuning or a combination of both for adjusting the antenna to resonance with the transmission frequency. The circuit arrangement of my invention will be more fully understood by detailed reference to the drawings. The same thing applies also to any tuned circuit which it is desired to be kept tuned at all times.

Referring more specifically to the drawings, reference character 1 designates an aircraft in flight, the aircraft being equipped with a radio transmitter having a trailing wire antenna 2,

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which is reeled off in varying lengths from antenna reel 3 installed in the aircraft 1. The radio transmitter carried aboard the aircraft 1 has been designated generally at 4 connected to the trailing wire antenna 2 through reel 3. The variable tuning device has been schematically shown at 5 disposed in series with the trailing wire antenna and the discriminator and automatic tuning control mechanism has been indicated schematically at 6. In Fig. 2 I have shown this schematic arrangement on a somewhat larger scale from which it will be observed that radio frequency energy is fed to the trailing wire antenna 2 through the variable tuning device schematically shown at 5. A portion of the energy incident upon antenna 2 is supplied through conductor to the discriminator and automatic tuning control schematically represented at 6.

Fig. 3 illustrates the arrangement of automatic tuning system in which energy supplied from the transmitter 3 is impressed upon the trailing wire antenna 2 through transmission line X, and loading coil 10. The antenna current in coil 10 induces voltage into coupled coil 11. The inductance 11 is connected to the differentially controllable discriminator 12 and automatic tuning control mechanism shown more clearly in Fig. 5. The automatic tuning control mechanism 12 variably controls through operating shaft 14 the variable capacitor 9.

In lieu of the variable capacitor 9 controlled from operating shaft 14, I may provide an inductive control mechanism constituted for example by the variometer or mutually adjustable inductance coils indicated at 15 disposed in series with the trailing wire antenna 2, and controlled by the discriminator and automatic tuning control mechanism represented at 12.

Referring to Fig. 5, the output of the aircraft radio transmitter is represented at 8 connected at one side to counterpoise 16 and at the other side to transmission line X. The trailing wire antenna 2 is shown with inductance 10 and variable capacitor 9 connected in series therewith. Inductance 10 induces voltage in inductance 11 which connects to the input circuit of a double rectifier designated by tube 18. The tube 18 may be a 6H6 tube containing cathodes 18a and 18a' and anodes 18b and 18b'. A mid-tap connection 19' extends from inductance 11 through condenser 20 to the transmission line X. This connection also extends to the differentially balanced circuit shown generally at 21. The differentially balanced circuit comprises resistances 22 and 22' each having a value of 75M and connected to the cathodes 18a and 18a' and through condensers 23 and 23' to the counterpoise again represented at 16. The condensers 23 and 23' each have a value of .004 microfarad. The mid-tap connection 19 taken from inductance 11 and which leads through the coupling condenser 20 to the transmission line terminates between the resistances 22 and 22' at 24. The differentially balanced circuit connects to a resistance network comprising the two resistances 25 and 25', each having a value of 50M and resistances 26 and 26', each having a value of 200M to the grid circuits of the double triode tube 27. The double triode may be a tube of the 6SC7 type and includes the common cathode 28, independent control grids 29 and 29' and their associated anodes 30 and 30'. The center point 31 of the network constituted by resistances 26 and 26' is supplied with potential from the power supply circuit which I have

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designated generally at 32 as including potentiometer 33 connected to a source of negative 20 volts at one end and to the counterpoise 16 at the other end and providing an adjustable variation for the impressed potential for the bias control of the double triode tube 27. The bias of tube 27 is adjusted to plate current cut off. The output circuits of the double triode tube 27 connect to the operating winding of the relays indicated at 35 and 35' from which windings a connection is taken to the positive potential source of the order of 325 volts, the return path from the source of plate voltage supply being completed through the counterpoise connection indicated at 16 connected to cathode 28. Relays 35 and 35' each control the movement of armatures which in turn control the operation of contact assemblies which have been designated diagrammatically at 36 and 36'. The relays 35 and 35' serve as control relays for determining the direction of rotation of the reversible motor system 37. Motor 37 is a 12 volt series wound D. C. motor containing the series connected field winding 38, commutator 39 and a magnetic clutch operating winding 40. The field winding 38 is connected at its opposite ends to the moving tongues of the spring pile-up assemblies operated by armatures 36 and 36'. When relay 35 is energized, the tongue of relay 35 moves to the right completing connection between the left hand end of series connected field winding 38 and contact 41, thereby controlling the rotation of the motor unit 37 in one direction. If relay winding 35' is energized, the tongue of the spring pile-up assembly 36' is moved to the left completing connection with contact 42, thereby reversing the direction of current flow through the series connected winding 38 of the motor unit 37 and reversing the direction of rotation of shaft 14 through reduction gear 43. As heretofore explained, the shaft 14 controls the angular adjustment of the variable capacitor 9. Relays 35 and 35' operate on 5 milliamperes and are so constructed that the relay tongues contact 41a and 42a respectively when relay windings 35 and 35' are deenergized. The motor unit remains stationary. The motor unit revolves only when the control circuit is differentially unbalanced and the direction of rotation is controlled according to the condition of unbalance.

When the trailing wire antenna is too short for the frequency of the energy from source 8, the capacitor 9 is revolved toward maximum capacity position and makes the trailing wire antenna circuit more inductive and brings the trailing wire antenna into resonance with the source 8.

When the trailing wire antenna 2 is too long for the frequency from the source 8, the capacitor 9 is revolved toward minimum capacity position and makes the circuit of the trailing wire antenna 2 predominately capacitive. The range of this particular configuration is from a short whip to approximately $\frac{3}{8}$ wave length on 3105 kc.

In the operation of the system of my invention a small portion of energy is transferred from the trailing wire antenna circuit 2 from inductance 10 to inductance 11 and impressed upon the double rectifier 18. Voltage is directly applied to the double rectifier from the transmission line X through condenser 20 and mid-tap connection 19 in winding 11. Thus a resultant voltage constituted by a combination of the induced voltage in winding 11 and the capacity coupled

voltage from line serves to excite the rectifier anodes 18b and 18b'.

Under conditions of resonance between the antenna circuit and the source 8, the currents through the resistors 22 and 22' indicated by arrows 45 and 45' are equal and opposite and therefore the voltage between the cathodes 18a and 18a' become zero. The purpose of the double rectifier 18 is to provide means for balancing the circuit and also to secure a positive voltage to excite the grids 29 and 29' of the double triode 27 under conditions of unbalance in the differential control circuit 21.

Voltage and current, across X and ground, are in phase from the untuned transmission line. This voltage is impressed without phase alteration to plates of diodes 18b and 18b', equal in phase and amplitude through blocking condenser 26 and coil 11. The diodes rectify the voltage, thereby causing equal and opposite polarity voltages to exist across resistors 22 and 22'. Between points E and F no difference in potential exists due to the canceling voltages across resistors 22 and 22'. Voltage L and M induced in coil 11 from coil 10 is applied to diodes 18b and 18b', 180 degrees out of phase but equal in amplitude. The diodes rectify the voltage, thereby causing equal and opposite polarity voltages to exist across resistors 22 and 22'. Between points E and F no difference in potential exists due to the canceling voltages across resistors 22 and 22'. At resonance of the circuit, the induced voltage in coil 11 is 90° out of phase with applied voltage X. The resultant impressed voltages may be designated as L and M at 180° phase displacement. Only the positive component affects the particular diode. Because the resultant voltages are equal in magnitude there is no potential difference between points E and F. When the antenna is too short for the resonant frequency, the phase between voltages L and X and M and X will depart from 90°. Since voltages L and M are 180° apart the phase angle between one of them and X will decrease while the other will increase. When the antenna is too long the reverse of this condition exists. As the voltages L and M shift a few degrees with relation to X one resultant which can be designated LX falls in magnitude and the other resultant which can be designated MX increases in magnitude. Since the resistors 22 and 22' receive the rectified resultant signals LX and MX the resistor 22' will have an increased voltage across it and resistor 22 will have decreased voltage. Point F now will have a positive voltage in relation to E due to the prescribed unbalance in voltages across resistors 22 and 22'. The voltage between points E and F is applied to resistors 26 and 26' which are in series and center feeds bias to relay control tubes which are at cut-off bias. Since point F is now positive in relation to point E, it is also positive in relation to point 31. This positive voltage cancels the negative bias on the control tube 30', thereby causing plate current to flow and close the relay, which in turn energizes the motor to orientate the tuning mechanism back to resonance. When the balance is restored the machine comes to rest. When the reverse tuning conditions are encountered, the converse of the preceding situations exist. It will also be noticed that when the transmitter frequency of wave length is changed the unbalanced condition then exists and the antenna is brought into resonance with the new frequency electrically without varying the phys-

ical length. The theoretical conditions as explained hereinbefore can be further emphasized as follows:

When the periodicity of the trailing wire antenna 2 is not correct for matching the frequency of the source 8, a direct current voltage difference between cathodes E and F is applied to control grids 29 and 29' of double triode 27, which was at plate current cut off; one grid receives additional negative bias which does not affect the already cut off condition, but the other grid receives positive voltage bucking off existing bias, thereby causing plate current to energize relay. Normally the currents through the relays 35 and 35' are zero. Normally the control grids 29 and 29' are biased from source 33 to cut-off which prevents the relays 35 and 35' from being energized but when the control circuit becomes unbalanced the differential current flows and one relay operates. This condition is shown in the curve diagram in Fig. 6 wherein the voltages between E and F of the control circuit have been plotted as ordinates while rotation of the tuning unit 9 has been plotted as abscissa. The voltage between E and F rises under conditions of non resonance, the motor unit 37 commences to revolve and moves tuning unit 9 to a position in which resonance is again restored, whereupon relay 35, which has been energized due to the differential current flow, is deenergized, shutting off the rotation of the tuning unit. Should the differential current commence to flow in the opposite path thus again disturbing the balanced condition, relay 35' is energized whereupon the motor unit 37 revolves in the opposite direction restoring the condition of resonance between the antenna circuit 2 and the transmitter 8.

I have constructed the automatic tuning system of my invention and have found the apparatus practicable in operation over wide variations. Where the trailing wire antenna is shot away or accidentally shortened the tuning unit of my invention operates automatically to restore a condition of electrical resonance for maintaining efficient transmission.

I have described my invention particularly as employing a series connected capacitor 9 in the trailing wire antenna circuit but it will be understood that I may employ a variometer as represented at 15.

While I have described my invention in certain preferred embodiments I desire that it be understood that modifications may be made and that no limitations upon my invention are intended other than may be imposed by the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. In a radio transmission system for aircraft, a radio transmitter, a trailing wire antenna, means for controlling the effective length of said antenna for effectively radiating energy within the frequency range of said transmitter, a tuning element disposed in series between said radio transmitter and said trailing wire antenna, a differential control circuit, a connection between said differential control circuit and said trailing wire antenna, means operated by said differential control circuit for adjusting said tuning element, said means operating under conditions of differences between the periodicity of said trailing wire antenna and the periodicity of said radio transmitter for adjusting said trailing wire antenna to resonance with said radio transmitter.

2. In a radio transmission system for aircraft

in combination a radio transmitter, a trailing wire antenna, means for controlling the extension or retraction of said antenna with respect to said transmitter for effectively radiating energy within the frequency range of said transmitter, a tuning element disposed in series between said trailing wire antenna and said radio transmitter, a differential control circuit coupled with said trailing wire antenna, a reversible motor controlled by said differential control circuit and operatively connected with said tuning element, said differential control circuit being normally balanced under conditions of substantial resonance between said trailing wire antenna and said radio transmitter and being unbalanced under conditions of off-resonance between said trailing wire antenna and said radio transmitter, said reversible motor being operative under conditions of unbalance of said differential control circuit for adjusting said tuning element and restoring said trailing wire antenna to a condition of substantial resonance with respect to said radio transmitter.

3. In a radio transmission system for aircraft, in combination, a radio transmitter, a trailing wire antenna, means for controlling the extension or retraction of said antenna with respect to said transmitter for effectively radiating energy within the frequency range of said transmitter, a tuning element disposed in series between said trailing wire antenna and said radio transmitter, a differential control circuit, means for both inductively and capacitatively coupling said differential control circuit with said trailing wire antenna, said differential control circuit being normally balanced for a condition of substantial resonance between said trailing wire antenna and said radio transmitter, a reversible motor operated by said differential control circuit, a connection between said reversible motor and said tuning element for adjusting said tuning element under conditions of unbalance of said differential control circuit for restoring said trailing wire antenna to substantial resonance with said radio transmitter.

4. A radio transmission system for aircraft comprising in combination with a radio transmitter, a trailing wire antenna, means for controlling the extension or retraction of said antenna with respect to said transmitter for effectively radiating energy within the frequency range of said transmitter, a tuning element disposed in series between the radio transmitter and the trailing wire antenna, a differential control circuit coupled with said trailing wire antenna, a reversible motor operated by said differential control circuit, means driven by said reversible motor for adjusting said tuning element between minimum and maximum, said motor operating when the trailing wire antenna is too short to efficiently respond to the frequency of said radio transmitter for moving said tuning element to maximum tuning position for restoring said trailing wire antenna to substantial resonance with said radio transmitter.

5. In a radio transmission system for aircraft, a radio transmitter carried aboard aircraft, a trailing wire antenna carried by the aircraft, means for controlling the extension or retraction of said antenna with respect to said transmitter for effectively radiating energy within the frequency range of said transmitter, a tuning device electrically connected between said radio transmitter and said trailing wire antenna, a differential control circuit, a reversible motor controlled by said differential control circuit, a mechanical connection between said reversible motor and said

tuning element for adjusting the position of said tuning element, means coupling said trailing wire antenna and said differential control circuit whereby conditions of non-resonance between said trailing wire antenna and said radio transmitter produce rotation of said reversible motor in a direction for moving said tuning element to a position restoring said trailing wire antenna to a condition of substantial resonance with said radio transmitter.

6. In a radio transmission system for aircraft, a radio transmitter carried aboard the aircraft, a trailing wire antenna, means for controlling the extension or retraction of said antenna with respect to said transmitter for effectively radiating energy within the frequency range of said transmitter, a tuning element coupling said trailing wire antenna with said radio transmitter, a reversible driving motor for controlling the position of said tuning element, a differential control circuit coupled with a trailing wire antenna and operating to control the direction of rotation of said motor for moving said tuning element between limits of maximum and minimum tuning positions, said differential control circuit operating under conditions of inequality between the frequency of said trailing wire antenna and the exciting frequency of said radio transmitter for adjusting the position of said tuning element for restoring substantial resonance between said trailing wire antenna and said radio transmitter.

7. In a radio transmission system for aircraft, a radio transmitter, a trailing wire antenna subject to continuous variation in physical length with respect to said radio transmitter and corresponding conditions of substantial resonance and non-resonance with said radio transmitter, a tuning device interconnecting said trailing wire antenna with said radio transmitter, a reversible motor for shifting the tuning device between limits of maximum and minimum tuning positions for adjusting any particular length of said trailing wire antenna for effectively radiating energy from said radio transmitter, a differential control circuit coupled with said trailing wire antenna, a relay system operated by said differential control circuit for controlling the direction and time of rotation of said reversible motor, said motor being operated under conditions of non-resonance between said trailing wire antenna and said radio transmitter for restoring said trailing wire antenna to a condition of substantial resonance with said radio transmitter.

8. In a radio transmission system for aircraft a radio transmitter, a trailing wire antenna, means for controlling the extension or retraction of said antenna with respect to said transmitter for effectively radiating energy within the frequency range of said transmitter, a variable condenser interconnecting said transmitter and said antenna, a coupling circuit disposed in said antenna, a differentially balanced circuit connected with said coupling circuit, a pair of relays controlled by said differentially balanced circuit, a reversible motor controlled for movement clockwise or counter-clockwise by said relays under conditions of unbalance of said differentially balanced circuit, and means driven by said motor for varying the capacity of said variable condenser for adjusting said trailing wire antenna to resonance with said radio transmitter and restoring a condition of balance of said differentially balanced circuit.

9. In a radio transmission system for aircraft, a radio transmitter, a trailing wire antenna,

means for controlling the extension or retraction of said antenna with respect to said transmitter for effectively radiating energy within the frequency range of said transmitter, a variable inductance interconnecting said transmitter and said antenna, a coupling circuit disposed in said antenna, a differentially balanced circuit connected with said coupling circuit, a pair of relays controlled by said differentially balanced circuit, a reversible motor controlled for movement clockwise or counter-clockwise by said relays under conditions of unbalance of said differentially balanced circuit, and means driven by said motor for varying the value of said variable inductance for adjusting said trailing wire antenna to resonance with said radio transmitter and restoring a condition of balance of said differentially balanced circuit.

10. In a radio transmission system for aircraft, a radio transmitter, a trailing wire antenna, means for controlling the extension or retraction of said trailing wire antenna with respect to said transmitter, for effectively radiating energy within the frequency range of said transmitter, a tuning element coupling said trailing wire antenna with said radio transmitter, a coupling circuit connected with said trailing wire antenna, an electron tube discharge system comprising a pair of diodes each constituted by a cathode and anode, connections between said anodes and said coupling circuit, a resistance network, connections between said cathodes and said resistance network, a connection between a mid-tap in said coupling circuit, said antenna, and said resistance network, a differential control circuit connected with said resistance network, and a reversible motor controlled by said differential control circuit, said motor operating to control the adjustment of said tuning element for maintaining the

frequency of said antenna in resonance with said transmitter.

11. In a radio transmission system for aircraft, a radio transmitter, a trailing wire antenna, means for controlling the extension or retraction of said trailing wire antenna with respect to said transmitter, for effectively radiating energy within the frequency range of said transmitter, a tuning element coupling said trailing wire antenna with said radio transmitter, a coupling circuit connected with said trailing wire antenna, an electron tube discharge system comprising a pair of diodes each constituted by a cathode and anode, connections between said anodes and said coupling circuit, a resistance network, connections between said cathodes and said resistance network, a connection between a mid-tap in said coupling circuit, said antenna, and said resistance network, said last mentioned connection being established with said antenna between the radio transmitter and the tuning element coupling the antenna with the transmitter, a differential control circuit connected with said resistance network, and a reversible motor controlled by said differential control circuit, said motor operating to control the adjustment of said tuning element for maintaining the frequency of said antenna in resonance with said transmitter.

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