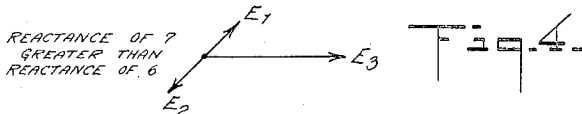
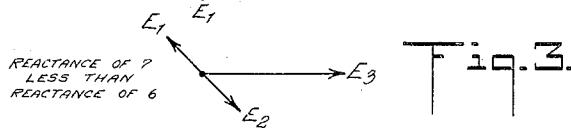
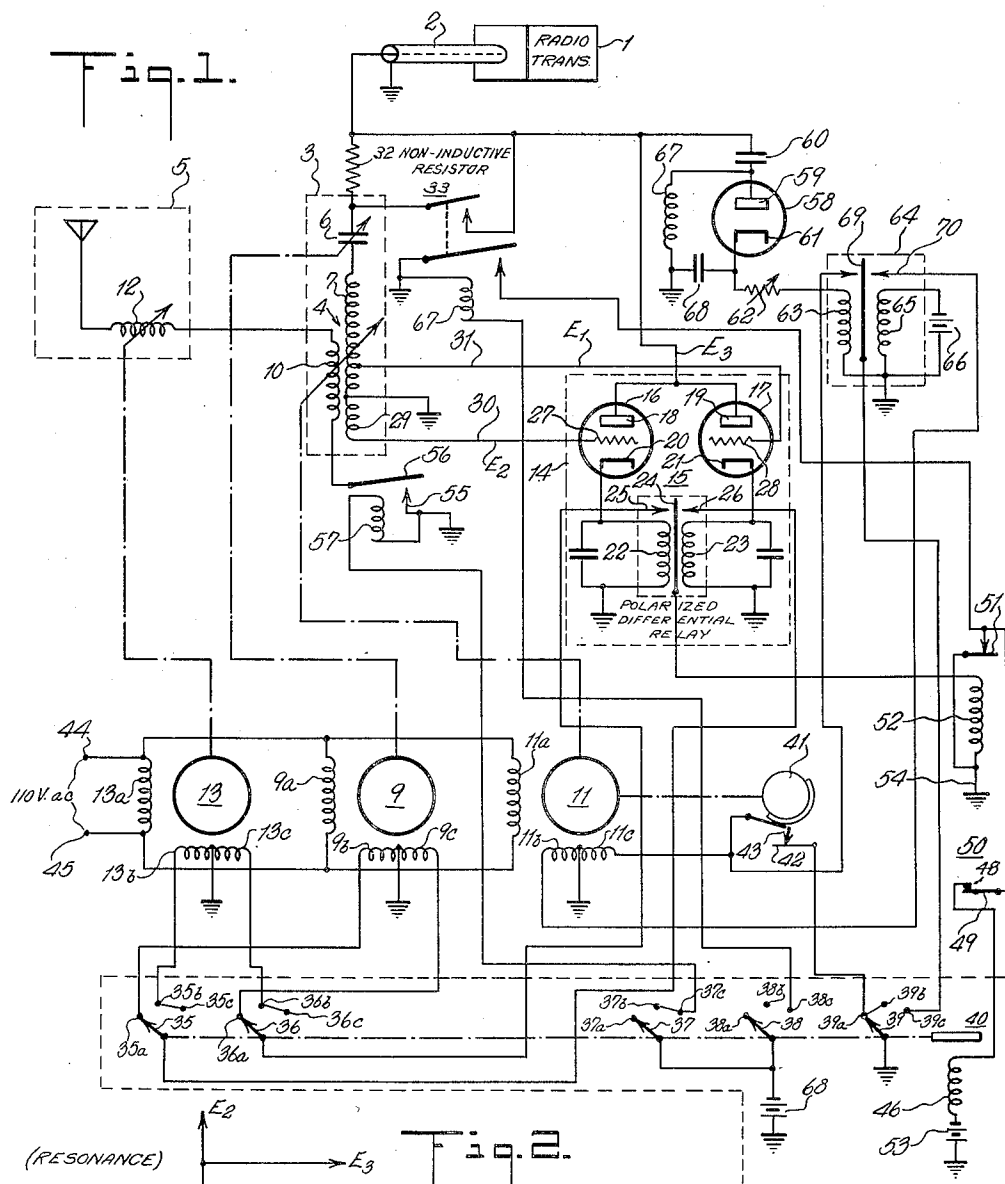


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REMOTELY CONTROLLED ANTENNA TUNING
AND LOADING SYSTEM
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REMOTELY CONTROLLED ANTENNA TUNING
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This invention relates to resonating systems and more particularly it relates to the automatic tuning and loading of high frequency circuits which are to operate in resonance.

A principal object of the invention is to provide an improved arrangement for remotely and automatically tuning the antenna circuit of a radio transmitter which is supplied from a wave transmission feeder line, providing a constant power output into the antenna circuit over a relatively wide operating antenna frequency.

Another object is to provide an arrangement for automatically tuning respective input and load circuits in successive steps while preserving the proper impedance relations during the successive steps.

Another object is to provide a simplified resonance discriminator arrangement for the automatic tuning or resonating of a plurality of coacting high frequency circuits.

A feature of the invention relates to an antenna system having means to adjust the loading of the antenna circuit, and separate means to resonate the coupling circuit between the antenna and a feeder line, and wherein special means are provided for maintaining the proper impedance relations between the coupling circuit and the line while the antenna is effectively decoupled from the line.

Another feature relates to the combination of an input wave transmission feeder line connected to a tunable terminating network designed to operate with a predetermined "Q"; the network being adjustably coupled to a tuned load, for example an antenna circuit which itself has an adjustable loading unit; and automatic means are provided for first tuning the terminating network to resonance while effectively decoupling the said network from the antenna and at the same time automatically maintaining the "Q" of the terminating network. Thereafter, the antenna is automatically resonated and the coupling device is automatically set to a predetermined coupling position, the foregoing operations being controlled by a simplified resonance discriminator of the dual electron tube type.

A further feature relates to the novel organization, arrangement and relative interconnection of parts which cooperate to provide an improved and simplified automatic resonating arrangement between a feeder line and a radio antenna.

Other features and advantages not specifically enumerated, will be apparent after a consideration of the following detailed descriptions and the appended claims.

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In the drawing,

Fig. 1 is a schematic wiring diagram of an automatic tuning or resonating system according to the invention.

Figs. 2, 3, and 4 are respective vector diagrams explanatory of the operation system of Fig. 1.

Referring to Fig. 1, the block 1 represents any well-known source of high or radio frequency waves, such for example as the output of the final amplifier of a radio transmitter. The output waves are applied to a wave transmission line 2, for example of the coaxial type, and thence to a terminating network 3, which is arranged to be adjustably coupled by means of a coupling unit 4, to the antenna circuit 5. The unit 3 comprises a series resonant circuit including the adjustable tuning condenser 6 and the inductance coil 7 having a tap 8 adjacent one end to develop a voltage E_1 . The adjustable element of condenser 6 is connected mechanically to the armature of a reversible electric motor 9. The unit 4 comprises an adjustably mounted antenna coupling coil 10 whose inductive coupling relation with respect to coil 7 can be adjusted by means of a reversible electric motor 11. The antenna circuit 5 includes the tunable inductance coil 12, whose adjustable element is connected to the reversible electric motor 13. Associated with the foregoing units is a resonance discriminator unit 14 including a polarized differential relay 15, which controls the direction of rotation of motors 9 and 13, in the manner to be described. The resonance discriminator 14 also includes a pair of grid-controlled electron tubes 16, 17, which may be of any well-known type. The plates 18, 19, of these two tubes are excited in phase and in parallel by a portion of the energy received from line 2. The cathodes 20, 21, are each connected to ground through a respective winding 22, 23, of the relay 15. The relay 15 is preferably of the neutral polarized differential type having an armature 24 and a pair of contacts 25, 26. When both windings 22, 23, are deenergized, or if they are energized equally, the armature 24 assumes a neutral position with respect to the associated contacts 25, 26. This condition therefore prevails when the anode-cathode current of tube 16 is equal to the anode-cathode current of tube 17. If however, the anode-cathode current of either tube predominates over that of the other tube, the relay 15 will be correspondingly energized and will move its armature 24 in either direction, depending upon which winding is predominantly energized.

The discriminator unit 14 operates upon the

principle that the control grids 27, 28, are always 180° out of phase, and for this purpose there is provided an additional inductance coil 29, which is tightly coupled with the coil 7. In fact, if desired, the coils 7 and 29 may be a single continuous winding with the midpoint of coil 29 connected to ground as shown. One end of coil 29 is connected by conductor 30 to grid 27 and the tap on coil 7 is connected by conductor 31 to grid 28. In other words, the grids 27 and 28 are always excited by the wave energy from line 2 to equal amounts but in phase opposition. If, for example, the voltage applied to the plates 18 and 19 is represented by E_3 ; the voltage to grid 28 is represented by E_1 ; and the voltage to grid 27 is represented by E_2 , then when the unit 3 is in resonance the vector relations between these three voltages are as indicated in Fig. 2.

Connected in series with the transmission line 2 and unit 3 is a non-inductive resistor 32, whose resistance is made equal to the characteristic impedance of the line 2, so that standing waves are minimized and the terminating network 3 presents the proper operating "Q" to the transmission line during that stage in the automatic resonating of the system when the antenna is decoupled from unit 6, as will be described. However, when the antenna circuit is being automatically loaded by coil 12 and motor 13, the resistor 32 is automatically short-circuited by a switch 33 as will be described. Preferably, although not necessarily, the discriminator tubes 16 and 17 are arranged so that the ratio of grid-to-plate voltages is comparable to the "mu" or amplification factor of each tube, so that the rectified grid currents of these tubes are small as compared to the rectified plate currents, and so that grid circuit variations reflect only slightly into the current flowing through the respective windings 22, 23. Associated with the various units described above, is a three-position five-gang switch 34, having five ganged movable switch arms 35, 36, 37, 38, 39, with a common stepping magnet 40 and with associated stationary contacts 35a, 35b, 35c; 36a, 36b, 36c; 37a, 37b, 37c; 38a, 38b, 38c; 39a, 39b, 39c. Motor 11 also rotates a switch operating cam 41 which controls the switch contacts 42, 43.

The motors 9, 11 and 13 may be of the shaded pole type, each having its field windings 9a, 11a, 13a, continuously energized from the 110 volt alternating current supply terminals 44, 45, and each having respective right-hand and left-hand phase windings or shading coils 9b, 9c; 11b, 11c; 13b, 13c. When, for example, a left-hand shading coil is short-circuited, the corresponding motor runs in a clockwise direction; if the right-hand shading coil is short-circuited, the motor runs in a counter-clockwise direction. When neither shading coil is short-circuited, the motor stops rotating. The circuit for energizing the winding 46 of the switch stepping magnet 40 is controlled by the normally closed contacts 48, 49, of a manually operable reset key 50, and by the contacts 51 of relay 52. When relay 52 is deenergized, its contacts 51 are closed, thus closing a circuit for the stepping magnet 46, traceable from battery 53, reset contacts 48, 49, contacts 51 to ground at 54. The shading coils of the motors have a transformer action with regard to the motor primaries 9a, 11a, 13a, and therefore develop a voltage across the shading windings. As either one of these windings is connected across a load, such as the coil 52, a current will

flow in this coil and in this case, if coil 52 has a low impedance compared to the shading windings the motor will operate with very little loss in efficiency and the relay 52 will be energized and operate its armature. Therefore, relay 52 has an operating circuit whose voltage source is the appropriate shading coil of the motor.

When energized, the stepping magnet 46 operates in the following manner: the armature 40 rotates a ratchet to which are attached the switch rotors 35—39. When the coil 46 of the stepping relay is de-energized, the actuating arm on 40 slips back on the ratchet with the moving switch sections 35—39, remaining in the previous position. It should also be pointed out that when the stepper is in position C and is again advanced, it will rotate again to position A and start the cycle over again.

When the stepping switch is in position #1, that is with the brushes 35—39 in engagement with contacts 35a—39a, the system is in condition to test and automatically adjust the tuning of unit 3. At the same time, the antenna coupling coil 10 is effectively decoupled at the normally open contacts 55, 56, of relay 57. In position #2, the relay 57 operates to couple the antenna circuit 5 to unit 3 by means of coil 10, and the coil 12 is automatically adjusted to tune the antenna circuit. In position #3, the coil 12 and the coil 10 remain under control of motors 13 and 11 so that correction can be automatically maintained for variations in the reactance and resistance existing at the end of line 2. Thus, the stepping switch remains in position #3 until a new frequency of transmission is being used, whereupon reset key 50 can be manually operated to restart the automatic tuning and antenna loading cycles.

For purposes of explanation, it will be assumed that key 50 has been momentarily operated for a new transmission frequency to be supplied over the line 2. Therefore, a circuit is traceable from battery 53, stepping magnet 46 to ground at key 50. This immediately advances the brushes of the stepping switch from position #3 to position #1. If the unit 3 is in resonance at the new frequency, the voltage and current developed across the line 2 are in phase, and the voltages E_1 and E_2 are in quadrature with voltage E_3 from the line. This condition is represented vectorially in Fig. 2 of the drawing. Thus, the grids 27 and 28 are excited equally and tubes 16, 17, conduct equally. As a result, windings 22 and 23 are equally energized and the armature 24 remains in neutral position.

If however, the reactance of coil 7 is greater than the reactance of condenser 6, as represented by the vector diagram of Fig. 4, tube 17 will conduct more than tube 16, and armature 24 will close with contact 26. If however, the reactance of coil 7 is less than the reactance of condenser 6, tube 16 will conduct to a greater extent and armature 24 will engage contact 25.

In order to measure the radio frequency voltage across the terminating load for the line 2, there is provided a diode 58 whose anode 59 is coupled to the load through condenser 60, and whose cathode 61 is connected through an adjustable resistance 62, to one winding 63, of a neutral differential polarized relay 64. The other winding 65 of this relay is steadily energized by battery 66. The rectified radio frequency energy flowing through winding 63 is thus balanced against the current through winding 65. The rectified voltage that is thus measured can be

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controlled by varying resistance 62. In other words, the winding 65 can be energized to a predetermined extent representing a predetermined radio frequency voltage across the load, and the resistance 62 can be adjusted so that when the system is in proper adjustment at the new frequency, the rectified signal through winding 62 balances the current through winding 65. A radio frequency choke coil 67 provides a D. C. return path to ground for the diode 53; and the condenser 68 by-passes the radio frequency energy to ground before it can pass through the winding 63.

With the stepping switch in position #1 as above described, the circuit of relay 57 is open at contact 37c, thus effectively decoupling the antenna circuit 5 from unit 3. Depending upon the relative magnitudes of the reactance of elements 6 and 7, the relay 15 will be selectively operated. If the relative magnitudes are such that the armature 24 is operated to engage contact 25, a circuit is traceable from ground 54, through relay winding 52, armature 24, contact 25, brush 36, contact 36a, winding 9c of motor 9, thus rotating the condenser 6 to resonate the unit 3. Thus the motor 9 rotates the condenser in the appropriate direction until resonance is obtained, whereupon armature 24 again assumes its neutral position. In this position, the circuit of relay 52 is broken and contacts 51 close to complete the circuit for stepping magnet 46, thus advancing the stepping switch to position #2.

It should be observed that during the first tuning operation in position #1 of the switch, motor 11 rotates the coupling coil 10 with respect to coil 7 until the switch contacts 42, 43, are opened, thereby stopping the rotation of motor 11. The cam 41 is so oriented that a predetermined value of coupling between coils 10 and 7 can be obtained. The degree of this coupling depends upon the resistance and reactance of the antenna, but it is not critical over a fairly wide range such as around one-quarter wave point. It is necessary that a certain amount of coupling be maintained between coils 10 and 7 since the operation of the discriminator depends upon the reflected reactance from the antenna circuit into coil 7. The formula for reflected reactance which is equal to formula

$$\frac{-JX_m^2X_a}{R_a^2 + X_a^2}$$

where X_m is the mutual reactance, R_a is the antenna circuit resistance, and X_a is the antenna circuit reactance. This shows that the reflected reactance is dependent directly on the reactance of the antenna circuit, and that it is inversely proportional to the sum of the resistance squared plus the reactance squared of the antenna circuit. Around the quarter wave point of the antenna, over say a 10% frequency range, the reactance and the resistance may be in the order of $-j200$ to $+j200$ and 60 to 70 ohms respectively, whereas around the half wave point, these values may be up in the thousands. This makes it necessary to adjust this coupling to a predetermined value which predetermined value must vary with the antenna used.

With the switch in position #2, the discriminator 14 now shifts its control from motor 9 to motor 13. In position #2, relay 57 operates over a circuit traceable from ground through the winding of relay 57, contacts 37c, 37b, switch arm 37 to grounded battery. Relay 57 when operated reconnects the coupling coil 10 in circuit with

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the antenna circuit. Because of the mutual coupling between coils 10 and 7, the reactance from the antenna and its associated elements will be reflected into coil 7, and thus will disturb the previous resonance phase condition existing between voltages E_1 and E_2 . This off-resonant condition again causes the appropriate one of the tubes 16, 17, to be predominantly conductive and therefore selectively determines the rotation of motor 13. It should be observed that in position #2 of the stepping switch, the contacts of relay 15 are connected to the #2 contacts 35b, 36b, and thence to the shading coils of motor 13. Motor 13 therefore rotates the adjustable element of coil 12 in the proper direction until the antenna circuit 3 is in resonance. The amount of mutual coupling required between coils 10 and 7 is a function of the "Q" of the antenna circuit, since the reflected reactance depends on the "Q" of that circuit. When the antenna circuit has thus been tuned to resonance, armature 24 again restores to neutral position, thereupon releasing the relay 52 and reclosing the circuit of the stepper magnet 46, thus advancing the stepping magnet to position #3.

It will be noted that in position #3, the shading coil of motor 13 still remains under control of the discriminator 14 by reason of the strap connection between contacts 35b, 35c, and 36b, 36c. In position #3 of the switch, a circuit is closed for winding 67 of switch 33, this circuit being traceable from ground, through winding 67, contact 38c, brush 38 to grounded battery 68. When switch 33 is thus operated, it short-circuits the resistance 32 and grounds contact 51 of relay 52 so that when the differential relay 24 returns in neutral position, it cannot advance stepper relay 46". This is necessary to prevent the stepper from advancing and going through the complete tune-up cycle again. In position #3, the motor 11 is placed under control of the relay 64 in the radio frequency voltage measuring circuit. If the rectified radio frequency voltage is below the value corresponding to the desired loading condition of the system, the winding 65 of relay 64 will take control and cause armature 69 to engage contact 70, thus closing a circuit traceable from ground, brush 39, contact 39c, armature 69, contact 70, winding 11b to ground. Motor 11 therefore again rotates the coil 10 in the proper direction to bring the rectified radio frequency voltage up to a point where it balances the steady current through winding 65. If however, the radio frequency voltage had been above the predetermined value corresponding to the desired loading, the winding 63 would have been predominantly energized and the winding 11a would have been short-circuited, thus rotating the coil 10 in the opposite direction. In either case, the coil 10 is rotated to correspond with the predetermined voltage condition that is required at the input to the unit 3. This voltage will of course be the voltage that is developed across the end of the line 2, where it feeds the unit 3 and will be equal to the characteristic impedance of the line. This resistance will consist of the lost resistance of coil 7 and the reflected antenna load resistance. When the foregoing operations have been thus automatically completed, the parts remain in their last set position and with the stepping switch in position #3, so that the system provides a continuous check and correction for any further variations in the reactance and resistance occurring at the end of the line 2 as it feeds the unit 3.

While certain specific embodiments have been described herein, it will be understood that various changes and modifications may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. In a wave transmission system having first and second sections arranged to be automatically adjusted to resonance, a resonance adjusting member for each section, a first motor for operating the member of the first section, a second motor for operating the member of the second section, adjustable coupling means between said sections, a resonance discriminator common to said sections, a third motor for automatically operating said coupling means, an impedance representing the equivalent loading of the second section on the first section when said first and second sections are coupled, means including said discriminator and said first motor to tune the first section to resonance while automatically inserting said impedance in circuit with the first section and while the said sections are decoupled, and means including said discriminator and said second motor for automatically tuning the second section to resonance while deleting said impedance.

2. A wave transmission system according to claim 1 in which means are provided for operating said third motor to increase the coupling between said sections while said second section is being tuned to resonance.

3. A wave transmission system according to claim 1 in which said discriminator includes a relay which controls the direction of rotation of said first and second motors.

4. A wave transmission system according to claim 1 in which said discriminator includes a relay which controls the direction of rotation of said first and second motors, and separate switch means are provided for controlling the direction of rotation of said third motor.

5. A wave transmission system according to claim 1 in which said discriminator includes a relay which controls the direction of rotation of said first and second motors, and a second relay for controlling the direction of rotation of said third motor, said second relay being operated independently of the first relay.

6. A system according to claim 1 in which said first section comprises a tuning condenser connected in series with said impedance, the adjusting member of said condenser being connected to said first motor.

7. A system according to claim 1 in which said first section includes a tuning condenser connected in series with said impedance and a coupling coil which coil is coupled to said adjustable coupling means, the said condenser having its adjusting member connected to said first motor, and said second section includes an adjustable inductance connected in series with said coupling means and having its adjusting member connected to said second motor.

8. A wave transmission system according to claim 1 in which said discriminator includes a polarized relay which controls the direction of rotation of said first and second motors.

9. In a wave transmission system having a first and a second tunable section to be automatically resonated to the frequency of waves from a source, first and second driving motors respectively for the tuning elements of said sections, a third driving motor for controlling the coupling of said sections, a resonance discriminator com-

mon to said sections, means including said third motor to effectively decouple said sections while inserting an equivalent impedance in circuit between said source and said first section, means including said discriminator and said first motor for automatically tuning said first section to resonance while said sections are decoupled, and means including said discriminator and said second motor for automatically tuning said second section and also increasing the coupling between said sections.

10. In a wave transmission system, a source of high frequency waves, a wave transmission line connected at one end to said source, a tunable network terminating the other end of said line, said network having first and second tunable sections coupled by an adjustable coupling element, said network having a predetermined "Q" when said sections are tuned to resonance and when they are coupled to a predetermined degree, means for automatically decoupling said sections and for automatically inserting an impedance to maintain said "Q," means for automatically tuning said first section to resonance while decoupled from the second section and while maintaining the insertion of said impedance, and means for automatically tuning said second section to resonance while maintaining said impedance deleted, and while increasing the coupling between said sections.

11. A wave transmission system according to claim 10, in which the said means for automatically tuning said first and second sections includes a resonance discriminator and a pair of motors respectively for the tuning elements of said sections, said resonance discriminator including a selectively reversible relay switch which is successively associated with said motors to control their direction and duration of rotation.

12. In a wave transmission system, a circuit to be automatically tuned to resonance with a source, a pair of grid-controlled tubes, means coupling the grids of said tubes to said circuit so that the grids are excited in opposite phase, means to excite the anodes of said tubes in like phase from said source, a motor for moving the resonance adjusting element of said circuit, and a relay selectively controlled by the differential anode-cathode currents from said tubes to cause said motor to operate until said circuit is tuned to resonance, said circuit including an inductance coil having a point intermediate its ends connected to the grid of one tube, and another inductance coil coupled to said first coil and having one end connected to the grid of the other tube.

13. In a wave transmission system, a circuit to be automatically tuned to resonance with a source, a pair of grid-controlled tubes, means coupling the grids of said tubes to said circuit so that the grids are excited in opposite phase, means to excite the anodes of said tubes in like phase from said source, a motor for moving the resonance adjusting element of said circuit, and a relay selectively controlled by the differential anode-cathode currents from said tubes to cause said motor to operate until said circuit is tuned to resonance, said circuit including an inductance coil connected in series between said line and ground, a point intermediate the ends of said coil connected to the grid of one tube, another coil connected between ground and the grid of the other tube and coupled to said inductance coil whereby the excitation of said circuit causes equal potentials but of opposite phase to be impressed upon the grids of said tubes.

14. In a wave transmission system, first and

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second tuned circuits to be resonated with a source, each of said sections having an individual tuning element, a first motor for said first element, a second motor for said second element, a third motor for controlling the coupling of said sections when the first section is being tuned to resonance and when the second section is being tuned to resonance, a resonance discriminator comprising a pair of grid-controlled electron tubes having their grids excited in opposite phase from said first circuit and their plates excited in like phase from said source, a three-position stepping switch effective in one position to control the first motor in response to the differential current from said tubes and effective in a second position to control the second motor in response to the differential current from said tubes, and circuits for automatically stepping said switch as each resonant condition is automatically reached, said tubes having their anode-cathode circuits differentially connected to the windings of a neutral polarized relay, said relay having contact

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sets for controlling the direction of rotation of the first and second motors, other relay means for controlling the direction and rotation of the third motor.

15 A wave transmission system according to claim 14 in which an equivalent non-inductive resistance is connected in series between the source and said first section, and a switch device is controlled by said third motor for shunting said resistance when the said second circuit is being adjusted to resonance.

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