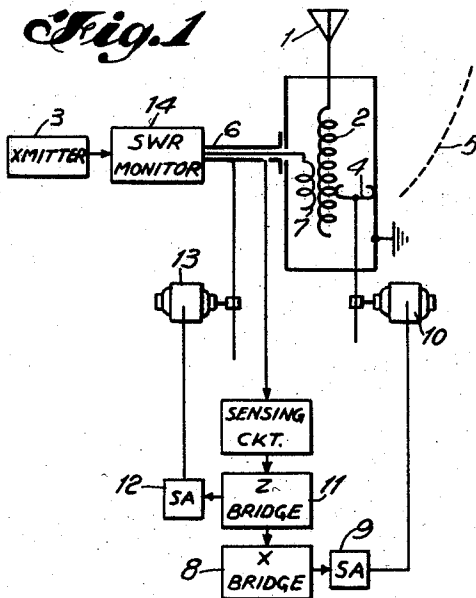
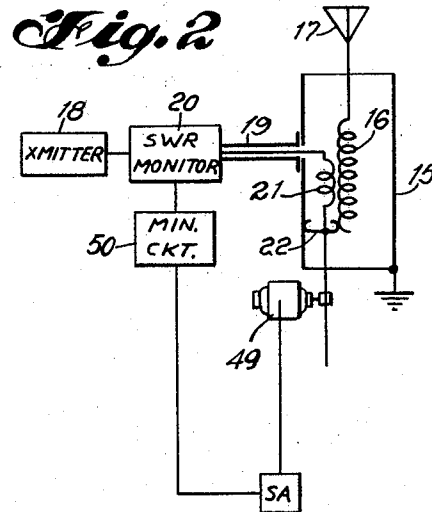
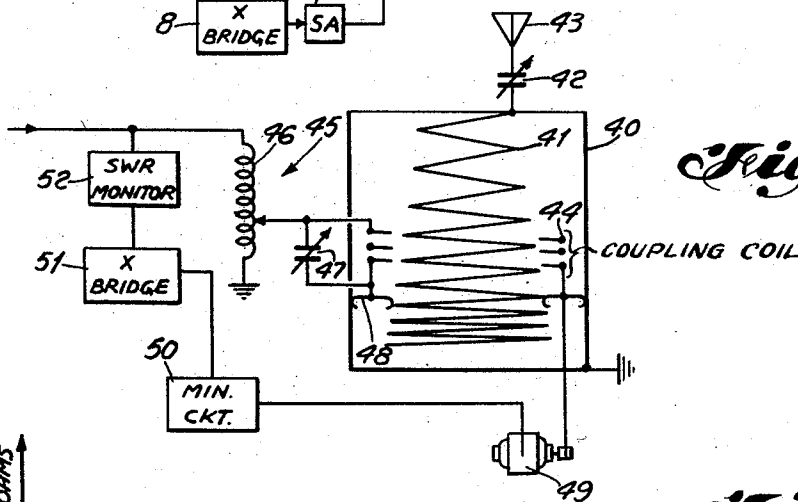
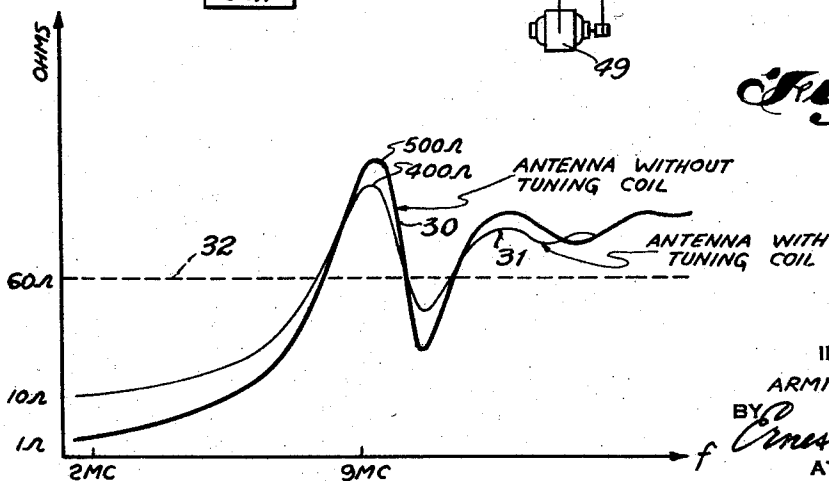


Oct. 7, 1958

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ANTENNA TUNING UNIT
Filed Aug. 5, 1955

2,855,599



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ANTENNA TUNING UNIT

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Application August 5, 1955, Serial No. 526,716

6 Claims. (Cl. 343—861)

This invention relates to antenna tuning units and, more particularly, to an antenna tuning unit which simultaneously matches the input impedance from a transmission line to an antenna to within a predetermined standing wave ratio over a wide frequency range while tuning the antenna.

When a transmitter operates into a transmission line having a given characteristic impedance such as 50 ohms, the combined effect of the distributed capacitance and inductance of the transmission line is to present a pure 50 ohm resistance (characteristic impedance) at the input of the line, which accepts power like an actual resistor but, instead of dissipating the accepted power as heat, causes the energy from the transmitter to travel down the transmission line in the form of a guided electromagnetic wave, called the incident wave. In the simplified case, this incident wave is the only effect present and the measured input impedance of the transmission line is simply 50 ohms, or the characteristic impedance. If the transmission line extends to infinite length or terminates in its characteristic impedance, simulating an infinite length, the load at the output terminals of the transmission line completely absorbs the energy of the incident wave as it arrives and thus, if the load is an antenna, maximum power is radiated. However, if the transmission line terminates in a load having an impedance differing from the characteristic impedance of the line, some energy is returned from the load, back into the transmission line in the form of a reflected electromagnetic wave traveling toward the input terminal. At the input terminal, this reflected wave appears as a voltage in series with the characteristic impedance. Depending upon the phase relationships, this reflected voltage may either aid or oppose the input voltage applied to the input terminals and thus, increase or decrease the input current. The effect in input impedance is higher if the reflected voltage opposes the flow of current and lower if the length of line is such that the reflected voltage arrives in aiding phase to the input voltage.

In every case where the line is not matched to the load or, in other words, where the load does not equal the characteristic impedance of the line, there is a reflected and incident wave present on the transmission line and the voltages at various points along the line are determined by the relative phase of these waves responsive to the distance of the point from the load. This variation of voltages with position along the line is called a standing wave and the ratio of the largest voltage, where the incident and reflected voltages add exactly in phase, to the smallest voltage, where the voltages are of nearly opposing phase and thus cancel, is known as the standing wave ratio or SWR.

When the load is matched, all the power coupled to the line is delivered to the load and the reflected wave is zero. Thus, for matched conditions, all points along the transmission line operate at the same voltage and the ratio of maximum to minimum voltage, or SWR, is 1. When the load is not matched, power is reflected and the reflected waves cause regions of high and low voltage along the line, producing a SWR greater than 1. Presence of

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a reflected wave, or a SWR greater than 1, indicates that some of the input power is not being absorbed or utilized by the load. In an extreme case, such as a short circuit or open circuit at the output terminals of the transmission line, all the power is reflected and the reflected wave equals the incident wave and thus, the minimum line voltage becomes zero giving an infinite SWR. Obviously, to avoid excessive voltage stress in the transmission line and, equally important, to deliver maximum useful power to the load, it is necessary to minimize the reflected wave with respect to the incident power and to adjust the load for the lowest standing wave ratio.

It has long been known that a typical antenna designed for optimum operation at a given frequency may be used for transmission over a range of frequencies provided the antenna is tuned and matched. A typical whip antenna, when properly tuned, has a voltage distribution extending from zero at the base and to a voltage maximum at the high impedance point at its far or terminating end. Somewhere between these two extremes, an impedance value can be found to which a transmission line having a given characteristic impedance can be coupled. Prior art teaches that to properly tune such an antenna over a frequency range, it has been necessary to adjust the length of the antenna to equal a quarter wavelength or multiple thereof and thus properly resonate at the transmitted frequency and, in addition, to vary the coupling characteristic between the transmission line and the antenna tuning unit or antenna structure in order to provide a proper impedance match between the transmission line and the antenna. Prior art automatic tuning devices have generally made two measurements, one of the reactance of the load and the other of the impedance of the load. Separate controlling elements were utilized to vary the length of antenna or tuning elements to provide minimum reactance and a second controlling element was utilized to adjust the coupling characteristic to match the characteristic impedance of the input transmission line. Thus, these prior art devices were primarily dependent upon two measurements which controlled in some manner two adjustments. Obviously, these two adjustments could be done automatically by incorporating separate servo loops for each measurement in each control unit.

One of the objects of this invention, therefore, is to provide a simplified antenna tuning unit to resonate an antenna at a given frequency within a wide frequency band and to match the antenna to an input transmission line by only a single adjustment.

Another object of this invention is to provide a simplified automatic antenna tuning unit in which a single adjustment varies both the reactance of the antenna unit and the input impedance of the unit to provide an acceptable standing wave ratio on the transmission line.

A further object of this invention is to provide a simplified automatic antenna tuning unit in which the coupling characteristic or impedance of the unit is varied as a function of the variation of the reactance of this system.

One feature of this invention is the use of tuning means in series with an antenna and to which mechanically coupled, is coupling means to couple energy between a transmission line and the antenna. As the tuning means is adjusted, to vary the effective length of the antenna, due to a modified coupling characteristic integral with the tuning unit, the coupling means matches the antenna impedance to the transmission line.

Another feature of this invention is the provision of an automatic antenna tuning unit including a helical tuning element connected to the antenna along which a movable short-to-ground is provided to vary the effective length of transmission line coupled to the antenna and thus resonate the antenna system at the frequency of

transmission. Power is coupled into the helical line of the tuner from the transmitter by means of a fixed coupling coil mounted on the movable short assembly instead of the adjustable coupling usually provided in antenna tuning units. Various degrees of coupling are integrated into the tuner by means of such devices as a non-uniform winding pitch on the helical tuning element or a varying diameter in the helical tuning element or a varying diameter of tuning element core to provide a variable capacitive characteristic along the tuning coil length, or similar means to insure that the coupling characteristic of the system maintains the input standing wave ratio on the transmission line below a predetermined level.

The above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a schematic diagram partly in block form of a typical prior art automatic antenna tuning unit;

Fig. 2 is a schematic circuit diagram partly in block form of an automatic antenna tuning unit in accordance with the principles of my invention;

Fig. 3 is a series of curves helpful in the explanation of the automatic antenna tuning unit shown in Fig. 2; and

Fig. 4 is a schematic view partly in cross-section of one embodiment of an automatic antenna tuning unit in accordance with the principles of my invention.

Referring to Fig. 1 of the drawings, a typical prior art automatic tuning unit for an antenna 1 is therein shown to include a helical tuning element 2. As will be readily understood by anyone skilled in the art, as the transmitter 3 is tuned over a range of frequencies, the antenna 1 is made to represent either an inductive or capacitive load. When the antenna represents an inductive load, the electrical length is made greater than a quarter wavelength but less than a half wavelength to make the tuner element capacitive and thus resonate the inductance of the antenna reactance, by varying the position of the movable short-to-ground 4 along the helical tuning element 2. This places a voltage null, shown by Curve 5, at the grounded point and places a high impedance at the radiator terminal of the antenna and thus, it is apparent that somewhere between the shorted point 4 and the terminal of the antenna 1 is a coupling position to which the incoming transmission line 6 may be matched. A coupling coil 7 is provided which is moved along the length of helical tuning element 2 until a proper impedance match is obtained between the antenna tuning unit and the transmission line 6. In order to automatically adjust the antenna tuning unit shown in Fig. 1, a reactance measuring bridge 8 is coupled to the transmission line 6 by any well known means and its output controls a servo amplifier 9 to which a motor 10 is responsive. The motor 10 adjusts the movable short along the length of the helical tuning element 2 until the reactance bridge 8 indicates a resonant point. Sequentially or simultaneously with the adjustment, an impedance measuring bridge 11 has its output coupled through a servo amplifier 12 to control motor 13 to move the coupling coil 7 along the helical tuning element 2 to provide a proper impedance match between the antenna tuning unit and the transmission line 6. If the two bridge circuits are operating properly, the standing wave ratio monitor 14 coupled to the transmission line 6 between the transmitter 3 and the antenna tuning unit will indicate a minimum standing wave ratio. However, it should be noted that such a system requires dual servo loops and two adjustments to be made independently of each other. Such a system is extremely complex and difficult to maintain, as well as construct and fabricate.

Referring to Fig. 2, the simplified automatic antenna tuning unit in accordance with the principles of my invention is therein shown, schematically, partly in block form. An automatic antenna tuning unit 15 comprising

a helical tuning element 16 in series with an antenna 17 is provided. The output of a transmitter 18 is coupled along transmission line 19 and through a standing wave ratio monitor 20 to a coupling coil 21 which induces the energy coupled from the transmission line 19 into the tuning element 16 for transmission by the antenna 17. A movable short 22 varies the length of helical line coupled to the antenna 17 and thus causes the antenna element to resonate at the frequency of the output of transmitter 18. Mounted on the movable short 22 is a fixed coupling coil 21 so arranged that if a proper reactance is attained by the positioning of short-to-ground 22, the coupling coil 21 will provide a reactance which is sufficient to have the standing wave ratio monitor indicate a SWR of less than 4 to 1 which is considered satisfactory and efficient for almost all transmission conditions.

Referring to Fig. 3 of the drawings, a graph is therein illustrated showing the variation of antenna resistance with a variation in frequency. The curve of 30 is illustrative of the resistance of an antenna without a tuning coil and it shows that, for example, at 2 mc. the antenna may have a resistance of 1 ohm and reach a resistance of 500 ohms at anti-resonance at 9 mc. and then continue to have its resistance value oscillate approximately 80 ohms. Curve 31 illustrates a similar resistance curve for an antenna in series with a tuning coil. The added resistance of the tuning coil at 2 mc. causes the system to have a higher resistance, such as 10 ohms, while at anti-resonance at 9 mc. the added resistance of the tuning coil causes the resistance of the antenna system to be only 400 ohms. Thus it can be seen that the added resistance of a tuning coil tends to flatten out the resistance curve of the antenna system. Assuming that it is desirable to match a 60 ohm transmission line to the antenna system, the resistance of which is indicated by the dotted line resistance level 32, and knowing the position of the resistance curve at 2 mc. and at anti-resonance at 9 mc., it is seen that the desired coupling factor may be designed as an integral part of the tuner so that the standing wave ratio on the transmission line will always be less than 4 to 1. This varying coupling factor may be made integral with the tuning unit by various devices, such as varying the pitch of the coil or tapering the coil diameter, so that at any point along the resistance curve the ratio of the antenna system resistance to the transmission line characteristic is less than 4 to 1. In any event the output of the SWR monitor is coupled through a minimum detector circuit 50 such as disclosed in copending application Serial No. 498,865 filed April 4, 1955 assigned to the same assignee as this application. The output of the minimum detector is amplified and drives motor 49 to stop the shorting means when a satisfactory SWR is attained. Due to the integrated coupling factor when the short is stopped a satisfactory match is achieved.

Referring to Fig. 4 of the drawings, one embodiment of an antenna tuning unit according to the principles of my invention is shown. The antenna tuning unit comprises an outer housing or shell 40 surrounding the main tuning coil 41. One end of the main tuning coil 41 is coupled through an adjustable capacitor 42 to the antenna unit to be tuned 43. A coupling coil 44 couples energy from a transmission line 45 into the main tuning coil 41. The energy from transmission line 45 is coupled through an autotransformer 46 and across an adjustable capacitor 47. Energy is supplied to the transmission line 45 from a transmitter 51 coupled through a standing wave ratio monitor 52. The length of main tuning coil 41 in series with the antenna 43 is varied by adjustment of the fingers 48 along the axial length of the helical tuning coil. Fingers 48 short out all turns of the tuning coil below their physical position since they make electrical contact with the housing 40 which is at ground potential. It should be noted that a varying coupling characteristic is inserted into the main tuning unit coil by varying the pitch of the winding and the diameter of the coil. It is of

course obvious that other methods of adjusting the coupling characteristic of this system may be used, such as a conductive core of varying diameter coaxial with the main tuning unit or means to physically rotate coupling coil 44 relative to the axis of the main tuning coil 41.

In operation, the shorting fingers 48 of the antenna tuning coil are moved to the top of the helix 41 by means of motor 49 and caused to start their descent. The shorting fingers are started at the top of the antenna tuning coil because for maximum efficiency it is desirable to have the minimum length in the antenna system. As a resonant condition is reached, i. e., a condition in which the length of antenna 43 plus the length of tuning coil 41 is equal to a quarter wavelength at their operating frequency, the standing wave ratio monitor 43 detects a SWR of less than 4 to 1 and thus couples a signal to motor 49 enabling the motor to cease moving the shorting fingers 48 and thus resonate the antenna system. If desired, a minimum sensing circuit may be utilized to anticipate the position at which the shorting fingers should be stopped to obtain the standing wave ratio desired. The coupling coil 44 is mounted in fixed relation to the shorting fingers at such a point that when the shorting fingers resonate the antenna system for the predetermined operating frequency, the coupling characteristic between the coupling coil 44 and the antenna tuning unit 41 provides a match for the transmission line 45. If a helix of constant diameter will not provide such a satisfactory match, then the diameter of the helix 41 may be altered to provide a different coupling characteristic for the particular frequency or the pitch of the winding may be altered so that when the fingers 48 are positioned in this location, the coupling characteristic will be satisfactory to provide a good standing wave ratio.

In order to extend the range of frequencies through which this antenna tuning system may be utilized, an additional tuning capacitor 42 may be added in series with 43 as is well known to those skilled in the art. If desired, at the operating frequency a variable capacitor 47 may be coupled across the coil 44 in order to resonate the coupling coil. In addition, the range of the antenna tuning unit may be extended by providing an autotransformer having a turns ratio in the order of 3 to 1 and thus extend the range over which a match can be attained.

It will be readily understood that since the coupling coil 44 is in fixed relation to 48 but a varying coupling characteristic is made integral in the design of the antenna tuning unit 41 that the coupling resistance or impedance will vary with the position of the shorting fingers. It is also obvious that by varying the diameter of a core member which could be added to the helical tuning unit, capacitive loading is obtained which could function as a top loading when the short circuit fingers 48 are in a position below the largest diameter of the core, which would act as a low impedance region. It is also obvious that varying the coupling characteristic varies the resonance frequency of this system and therefore enables the coupling coils to match the impedance of the transmission line.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention, as set forth in the objects thereof and in the accompanying claims.

I claim:

1. An antenna tuning and coupling unit for coupling energy over a wide band of frequencies from a transmission line to an antenna comprising, an inductance coil in series with said antenna, adjustable shorting means to short circuit to ground a variable portion of said coil to adjust the effective electrical length of said antenna and coil, means mechanically coupled to said adjustable shorting means for movement therewith to couple energy between said transmission line and said coil, means to

modify the coupling characteristic between said coil and said coupling means in accordance with the position of said coupling means relative to said coil for each position of said adjustable shorting means.

2. An antenna tuning unit for coupling energy over a wide band of frequencies from a transmission line to an antenna comprising, a helical tuning coil in series with said antenna, adjustable shorting means to short circuit to ground a variable portion of said tuning coil to adjust the effective electrical length of said antenna and tuning coil, means carried by said adjustable shorting means to couple energy between said transmission line and said tuning coil, means integral with said tuning coil to vary in a non-uniform manner along the axial length of said helical tuning coil the coupling characteristic between said tuning coil and said coupling means.

3. An antenna tuning unit for coupling energy over a wide band of frequencies from a transmission line to an antenna comprising, a helical tuning coil in series with said antenna, adjustable shorting means to short circuit to ground a variable portion of said tuning coil to adjust the effective electrical length of said antenna and tuning coil, means carried by said adjustable shorting means to couple energy between said transmission line and said tuning coil, said helical tuning coil having a non-uniform winding pitch whereby the coupling characteristic between said tuning coil and said coupling means is altered responsive to the position of said adjustable shorting means.

4. An antenna tuning unit for coupling energy over a wide band of frequencies from a transmission line to an antenna comprising, a helical tuning coil in series with said antenna, adjustable shorting means to short circuit to ground a variable portion of said tuning coil to adjust the effective electrical length of said antenna and tuning coil, means carried by said adjustable shorting means to couple energy between said transmission line and said tuning coil, said helical tuning coil having a non-uniform diameter whereby the coupling characteristic between said tuning coil and said coupling means is altered responsive to the position of said adjustable shorting means.

5. An antenna tuning unit for coupling energy over a wide band of frequencies from a transmission line to an antenna comprising, a helical tuning coil in series with said antenna, adjustable shorting means to short circuit to ground a variable portion of said tuning coil to adjust the effective electrical length of said antenna and tuning coil, a coupling coil carried by said adjustable shorting means in fixed relation thereto to couple energy between said transmission line and said tuning coil, means integral with said tuning coil to modify the coupling characteristic between said tuning and coupling coils for each position of said adjustable shorting means.

6. An antenna tuning unit for coupling energy over a wide band of frequencies from a transmission line to an antenna comprising, a coaxial structure including an outer conductive casing member, a helical tuning coil in series with said antenna and disposed in coaxial relation to said casing member, adjustable shorting means to couple a point on said helical coil to said casing member, a coupling coil carried by said adjustable shorting means coaxial to said tuning coil to couple energy between said transmission line and said tuning coil, means integral with said tuning coil varying in a non-uniform manner along said tuning coil's axial length to modify the coupling characteristic between said tuning coil and said adjustable shorting means.

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