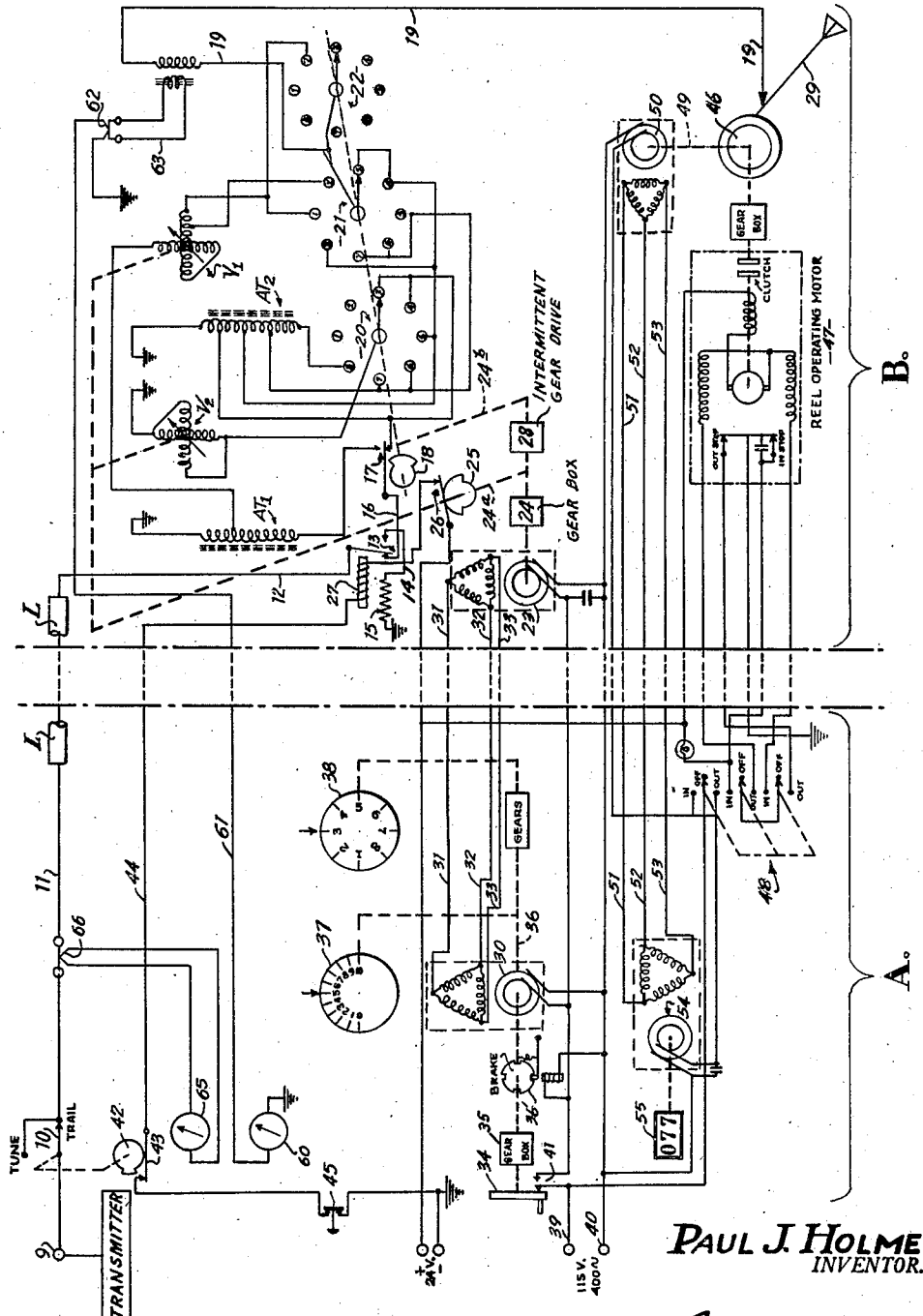
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REMOTELY CONTROLLED ANTENNA TUNING APPARATUS

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PAUL J. HOLMES,
INVENTOR.

BY Alfred W. Kingsford

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REMOTELY CONTROLLED ANTENNA TUNING APPARATUS

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

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This invention relates to the art of radio communication, and pertains particularly to apparatus whereby efficient transmission of radio frequency power from a radio transmitter to a remotely located antenna is obtained under the variable conditions resulting from the use of different antennae, or the same antenna adjusted to different transmitting lengths.

One of the particular objects of the invention is to provide a tuning apparatus adapted to provide efficient transmission of radio frequency power from an aircraft radio transmitter to a trailing wire antenna located on the aircraft at a position remote from said transmitter.

A further object of the invention is to provide a tuning apparatus adapted for the efficient transmission of radio frequency power as above set forth, together with means for tuning the trailing wire antenna by remote control from a position at or adjacent the transmitter.

A further object of the invention is to provide an apparatus of the character described, wherein the transmission of radio frequency power from the transmitter to the remotely located antenna is accomplished in the substantial absence of reflected waves in the transmission line, thereby eliminating energy-wasting standing waves in the transmission system. Another object of the invention is to provide for the tuning of a transmitter under the stabilizing influence of a substantially constant predetermined impedance which terminates the transmission line, such impedance having a value substantially equivalent to the impedance of such transmission line, and the subsequent tuning of the antenna circuit to a impedance value substantially duplicating such constant predetermined impedance with the transmission line connected to the antenna, whereby progressive readjustments of both transmitter and antenna are obviated in the tuning operation.

A further object of the invention is to provide a tuning apparatus adapted for the efficient transmission of radio frequency power from a radio transmitter to a remotely located antenna through the agency of a transmission line of a given impedance, wherein the transmitter is first tuned while the transmission line is terminated by a fixed reference load substantially matching said given impedance, and whereafter the desired antenna may be substituted for said fixed reference load and tuned to an impedance value substantially matching said given impedance, whereby standing waves and attendant losses in the transmission line are reduced to a minimum.

A further object of the invention is to provide a device for the efficient transmission of radio frequency power from a radio transmitter to a remotely located antenna at varied transmission frequency ranges or bands, wherein the described

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antenna tuning is effected to the required impedance at any selected frequency range.

In the transmission of radio frequency power to an aircraft antenna, two alternative procedures are conventionally employed. In one procedure, the antenna is connected directly to the transmitter and extended exteriorly of the aircraft as expeditiously as possible. This results in the portion of the antenna which is the most effective as an energy radiator being located within the aircraft, where it is shielded and prevented from radiating properly, and, owing to the attempts which have been made to shorten the shielded portion to the maximum extent, this trailing antenna is in some cases extended from the aircraft at a position such as to present a hazard to the operation of the aircraft as a result of the whipping of the antenna about in the airstream. The second procedure is that of using the so-called "co-axial" type of transmission line or cable from adjacent the location of the transmitter to a remotely located point near where the antenna extends from the aircraft, whereby the major portion of the radiating antenna is located outside the shielding action of the aircraft body. This latter procedure makes possible the extension of the antenna from a position such as the tail of the aircraft where minimum hazard is presented, but the problem of tuning the system by adjusting the transmitter and the length of the antenna presents considerable difficulty. More specifically, it is found that adjustment of the antenna produces an effect upon the tuning of the transmitter, and vice versa, making necessary progressive adjustments of both elements. During the adjustment process, standing waves are created; these standing waves produce a reactive component which, in effect, is interposed between the transmitter and antenna ends of the transmission line. The magnitude and angle of this reactance varies with both the transmitter and antenna tuning, resulting in an interlocking in which the adjustment of the transmitter is dependent upon the adjustment of the antenna, and vice versa, creating a very undesirable condition.

According to the present invention, I provide a fixed reference load for terminating the transmission line with a load which matches the impedance of the transmission line and permits ready tuning of the transmitter, and provide means for tuning the antenna to present substantially this same impedance value to the line in substitution for the fixed reference load so no retuning of the transmitter is necessary. The establishment of the fixed reference load and the tuned antenna at substantially the characteristic impedance of the transmission line results in a minimization of the losses resulting from the production of standing waves in the transmission

line, by the substantial elimination of such standing waves.

The apparatus of the present invention comprises, essentially, means for tuning and matching an antenna to its remotely located exciting transmitter, through the agency of controls located at such transmitter, said tuning and matching means including a connecting transmission line, a terminating dummy impedance substantially matching the impedance of said transmission line, means for tuning the antenna, transformer means associated with said antenna and associable with said transmitting line and adapted to adjustment for matching the impedance of said antenna to the characteristic impedance of the transmission line, and means for alternatively connecting said dummy impedance and said transformer means to said transmitting line, together with means for indicating antenna current remotely at said transmitter and means for indicating input current to said transmission line.

In a preferred embodiment, the transformer means is adaptable to adjustment over the range of transmitting frequencies for which the transmitter is adapted to function. According to my present contemplation, such transformer means includes one or more auto-transformers associated with inductance coupling means adapted to produce an adjustment in the inductive component of reactance of the load imposed upon the transmission line by the antenna in compensation for the variation of the capacitative component of reactance experienced in varying the length of the radiating antenna. The switching of the auto-transformers to different wave bands, and the adjustment of the inductive coupling are accomplished through the agency of controls located at the transmitting end of the transmission line, at or adjacent the location of the transmitter itself, so that one operator has both the transmitter and the tuning devices under control.

The accompanying drawing schematically represents an illustrative embodiment of the invention, as applied to an aircraft radio utilizing a trailing wire antenna. This embodiment is of the so-called "multiple band" type of apparatus, adapted for use with a transmitter capable of generating useful radio frequency power over a wide range of frequencies. Other objects and features of the invention will be brought out in the ensuing description of this embodiment, or will be apparent therefrom.

Referring to the drawing the portion at the left-hand side of the drawing and indicated by bracket A is adapted to be located immediately adjacent the transmitter, not shown, and may be considered the "tuning" unit; the portion at the right-hand side of the drawing and indicated by bracket B is adapted to be located remote from the transmitter, at the other end of the transmission line and at or near the point of exit of the trailing wire antenna from the aircraft body. This latter portion of the apparatus may be considered the "antenna" unit. The two portions are interconnected through the agency of a transmission line L which is of a shielded or "co-axial" construction, together with certain other conductors for the establishment and operation of the various tuning controls which are variously referred to hereinafter.

The terminal indicated at 9 in the tuning portion is intended for connection with the antenna terminal of the transmitter, and leads through a two position switch 10 which is adapted to provide alternative connection to (*a*) a trailing wire antenna (shown as the "trail" connection), (*b*) a fixed dummy non-inductive resistance element which is utilized during the transmitter tuning operation. In the "trail" and "tune" positions of switch 10 the terminal 9 is connected to lead 11 to the transmission line L, thence to the antenna unit where it connects with a lead 12 to the armature of a double-throw single pole switch 13, one side of which is connected through lead 14 to a fixed non-inductive resistance element 15 and thence to ground. The switch 13 is controlled to connect the transmitter output into the element 15 in condition (*b*), above. The other side of switch 13 connects through lead 16 to the antenna tuning network, to provide a condition (*a*) connection, as to the armature of a second double-throw single pole switch 17 which is adapted to provide alternative connection to two auto-transformers AT_1 and AT_2. In this specific disclosure, AT_1 is the low-frequency member adapted for use upon two of the eight frequency bands for which the apparatus is arranged, as for frequencies between 200 and 500 kc., and AT_2 is the high-frequency member adapted for use upon the remaining six of the eight bands for frequencies of 1500 to 12,500 kc. A switch operating cam 18 is provided to establish the armature of the switch 17 in connection with AT_1 during operation on the first two bands, said armature being spring biased into connection with AT_2 during operation in the six other bands.

The switching between the several bands is obtained through a band-switching gang switch, the elements of which are indicated at 20, 21 and 22; element 20 is utilized to control the varied connections to AT_2 and its associated variometer V_2, and elements 21 and 22 being utilized to control the varied connections to the antenna 29 through line 19, and the low-frequency variometer V_1 which is associated with the transformer AT_1 and utilized on the first two bands.

The variometers V_1 and V_2 are adapted for rotation through 360°, through 180° of which movement the desired minimum to maximum tuning coupling is attained, and during the remainder of the 360° movement the band-switching operation is conducted upon the elements 20—22. The rotation of the variometers and the operation of the elements 20—22 as well as the switch cam 18, above mentioned, is effected through a self-synchronizing motor 23, the motor being geared down as through a gear box 24, from which a drive shaft 24*a* extends to drive a cam member 25 and the two variometers. The cam member 25 is adapted to control a switch 26 governing a relay 27 which operates the armature of the switch 13. The cam 25 maintains the power supply circuit to the relay 27 closed during the 180° of tuning movement of the variometers, which connects the armature to lead 16 and thus connects the radio frequency power into the antenna tuning network through switch 13, but connects this power into the dummy impedance 15 during the band-switching operation which occurs in the other 180° of movement of the variometers V_1 and V_2. An intermittent gearing such as a Geneva gear may be provided as at 28 to effect the desired band-switching operation of the elements 20—22, through a drive shaft indicated at 24^b, this shaft also being utilized to drive the cam 18.

The motor 23 is electrically locked with a corresponding control motor 30 in the tuning portion of the apparatus, through connecting field leads 31, 32 and 33. The motor 30 is adapted for rotation through the agency of a tuning crank 34,

through an appropriate gear box 35, the drive shaft 36 being extended to effect operation of a tuning scale 37 and a band-indicating scale 38 through suitable gearing such as to cause movement of the tuning scale 37 in consonance with the movement of the variometers V_1 and V_2 and movement of the band scale 38 in consonance with the movement of the band-switching elements 20—22, as will be apparent to one skilled in the art. Power for operation of the motors 23 and 30 may be obtained through power supply connections 39 and 40 providing 115 volts at 400 cycles, for example. Inasmuch as it is necessary to supply power to the motors 23 and 30 only when the operation of the band-switching or the variometer tuning is desired, I preferably provide a power supply switch 41 under control of the crank 34 so that the power supply is connected only when the crank is arranged in operating position. I preferably also provide a magnetic brake on the shaft 36, as at 36', which prevents rotation of the shaft 36 unless the switch 41 is closed by placing the crank 34 in operating position.

When the switch 10 is placed in "tune" condition, at which position the radio frequency generator or transmitter is intended to be tuned to its desired operating condition, a cam 42 is operated to open a switch 43 in the current supply circuit 44 for the relay 27, thus causing the relay 27 to connect the radio frequency power into the fixed dummy impedance 15. A normally closed push-switch 45 is also provided in this circuit 44 for the purpose of momentarily connecting the radio frequency power to the dummy impedance during the adjustment of the final balance of the tuning and antenna portions of the apparatus, as hereinafter described.

The adjustment of the length of the trailing wire antenna 29 is obtained through a motor driven reel 46, the motor for which is indicated at 47, together with switch controls indicated at 48. The motor driven reel may be conventional, such as the U. S. Army Air Corps antenna reel RL—42. I preferably extend a shaft as indicated at 49 from the reel 46 to a self-synchronous motor 50 which is interlocked through field connections 51, 52 and 53 with a similar motor 54 at the tuning portion A of the apparatus, which latter motor is connected to a counter 55 which indicates the footage of antenna which is reeled out in any given condition of operation. Power supply for the motor 47 and the motors 50 and 54 will be conventionally supplied by direct current battery and the alternating current source used for the motors 23 and 30, respectively.

The operation of the apparatus is as follows:

The switch 10 is adjusted to "tune" position, which opens the switch 43 and connects the dummy impedance 15 to the transmission line L to act as a termination of such transmission line. The value of the impedance 15 is selected so as to be substantially a match for the impedance of the line L. The transmitter or radio frequency generator associated with the apparatus is then tuned to the desired operating frequency, the transmitter being adjusted so that the proper plate current is obtained therein, according to conventional practice. Assuming that the trailing antenna has a maximum length of 200 feet, if the transmitting frequency is within the range of the first two bands (200 to 500 kc.) the entire length of the antenna may be run out by operation of switch 48. The switch 10 may then be set to "trail" position, and the tuning crank 34 rotated until the desired band is indicated at 38. With the transmitter operating, the tuning crank is slowly rotated to cause operation of the variometers V_1 and V_2 (only V_1 will be functioning in the circuit in bands 1 and 2, as above described) until the maximum antenna current is indicated in the antenna ammeter 60 which is connected through lead 61 to a thermocouple 62 operated by a transformer-coupled circuit 63 arranged on the antenna lead 19. The equipment is properly tuned when the maximum antenna current is indicated.

When a frequency in the higher ranges is employed, the tuning procedure is changed as a result of utilizing an antenna length which is related to the wave-length of the radiated frequency, such as ¼, ¾ or 5/4 wave-length. The connections shown in the drawing are arranged for transmission on the third frequency band, utilizing the transformer AT_2 and the variometer V_2, and referring to the tuning operation with the apparatus so arranged and the transmitter properly tuned:

The switch 10 is turned to "trail" position, making sure that the tuning scale 37 is at zero position and the band scale 38 is at band No. 3 as shown. The proper length of trailing antenna for the particular frequency employed is then ascertained and by means of the reel control switch 48, the antenna is reeled out until the point of maximum antenna current (as indicated at 60) is just passed. The antenna is then reeled in until slightly less than the maximum antenna current is indicated at 60. The values of the transmitter plate current (above mentioned) and the line current (as indicated by line ammeter 65 controlled by thermocouple 66 operating off line 11) are then noted. The objective of the tuning operation is to have the transmitter plate current meter and the tuning unit line meter indicate constant values when the radio frequency power is switched from the dummy impedance 15 into the antenna tuning network; when these values are constant in both conditions of connection, it is certain that the impedance value of the antenna has been adjusted to the value of the dummy impedance 15, which was predetermined to have the proper value for the transmission line L. After noting the transmitter plate current and the line current values as above described, the button 45 is then pressed to convert the connections to the "tune" condition (the push-button switch performing the same function as the cam-operated switch 43). The reading on the transmitter total plate current meter and the reading on the line ammeter 65 are then observed, and compared to those obtained before the push-button 45 was pushed in. Usually there will have been a change. The push-button switch 45 is then released, and the tuning crank 34 is rotated until the line current at 65 is brought roughly half way from the first indicated value towards that obtained when the button switch 45 was pressed. The transmitter total plate current meter is then observed, and the trailing antenna is then reeled in or out until the total plate current meter indicates roughly half way towards the value obtained when the push-button switch 45 was pressed. The tuning crank 34 is then rotated until the line current indication at 65 is the same when the switch 45 is pressed or released. The trailing length of the antenna is then adjusted either in or out until the total plate current meter indicates the same value when the switch 45 is pressed or released. This readjustment of the tuning crank 34 and the antenna

length as indicated by the counter **55** may be repeated until the respective meters remain constant in the in and out positions of the switch **45**. The tuning indication (scale **37**) may be thought of as controlling the line current (ammeter **65**), and the length of trailing antenna (counter **55**) may be thought of as controlling the transmitter total plate current indication. After the tuning operation is completed the antenna current (ammeter **60**) will be approximately the same or greater than that obtained when the length of trailing antenna was first adjusted.

The above description sets forth a specific embodiment of this invention and modifications therein will occur to those skilled in the art. For this reason I do not choose to be limited to the specific details herein illustrated and described.

I claim:

1. Means for tuning and matching an antenna to its exciting transmitter, said antenna being remote from the transmitter and the controls for said means being located adjacent said transmitter, said means comprising: a connecting transmission line; a terminating dummy impedance matching said line; means for tuning said antenna; transformer means for matching the impedance of said antenna to a value substantially equal to the impedance of said dummy impedance; means for alternatively connecting said dummy impedance and said transformer to said line; and means for indicating input current to said transmission line.

2. Means for tuning and matching an antenna to its exciting transmitter, said antenna being remote from the transmitter and connected thereto through a transmission line having a characteristic impedance, said means comprising: a control unit located closely adjacent said transmitter; an antenna unit located adjacent said antenna, said antenna unit being connected to said control unit and said transmitter through said transmission line; a dummy impedance located at said antenna unit, said dummy impedance having an impedance value substantially that of said characteristic impedance; tuning means for varying the effective length and the capacitative reactance of said antenna; transformer means coupled to said antenna for varying the inductive reactance thereof whereby the impedance of said antenna may be adjusted to said characteristic impedance; switching means for alternatively connecting said dummy impedance and said transformer means to said transmission line; and current indicating means at said control unit for indicating the current value in said transmission line when arranged in said alternative connections.

3. Means for tuning and matching an antenna to its exciting transmitter, said antenna being located remote from said transmitter and the controls for said means being located adjacent said transmitter, said means comprising: a connecting transmission line; a terminating dummy impedance matching said line; means for tuning said antenna; transformer means including variable inductance coupling means for matching the impedance of said antenna to a value substantially equal to the impedance of said dummy impedance; means for alternatively connecting said dummy impedance and said transformer means to said line, and means for indicating input current to said transmission line.

4. Means for tuning and matching an antenna to its exciting transmitter, said antenna being located remote from said transmitter and connected thereto through a transmission line having a characteristic impedance, said means comprising: a control unit located closely adjacent said transmitter; an antenna unit located adjacent said antenna, said antenna unit being connected to said transmitter through said transmission line; circuit means interlocking said units in operative association; a dummy impedance located at said antenna unit, said dummy impedance having an impedance value substantially that of said characteristic impedance; tuning means for varying the effective length and the capacitative reactance of said antenna; transformer means at said antenna unit coupled to said antenna through the agency of variable inductance coupling means for varying the inductive reactance of said antenna whereby the impedance of said antenna may be adjusted to said characteristic impedance; switching means at said antenna unit for alternatively connecting said dummy impedance and said transformer means to said transmission line; and current indicating means at said control unit for indicating the current value in said transmission line when arranged in said alternative connections.

5. Means for tuning and matching an antenna to its exciting transmitter, said antenna being located remote from said transmitter and connected thereto through a transmission line having a characteristic impedance, said means comprising: a control unit located closely adjacent said transmitter; an antenna unit located adjacent said antenna, said antenna unit being connected to said transmitter through said transmission line; circuit means interlocking said units in operative association; a dummy impedance located at said antenna unit, said dummy impedance having an impedance value substantially that of said characteristic impedance; tuning means for varying the effective length and the capacitative reactance of said antenna; transformer means at said antenna unit, said transformer means comprising tapped transformer means adapted for selective adjustment to any one of a plurality of transmitting frequency bands and being coupled to said antenna through the agency of variable inductance coupling means for varying the inductive reactance of said antenna whereby the impedance of said antenna may be adjusted to said characteristic impedance at any transmitting frequency within said plurality of frequency bands; switching means at said antenna unit for alternatively connecting said dummy impedance and said transformer means to said transmission line; and current indicating means at said control unit for indicating the current value in said transmission line when arranged in said alternative connections, said control unit including means for effecting selective adjustment of said transformer means and variation of said coupling means.

PAUL J. HOLMES.

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