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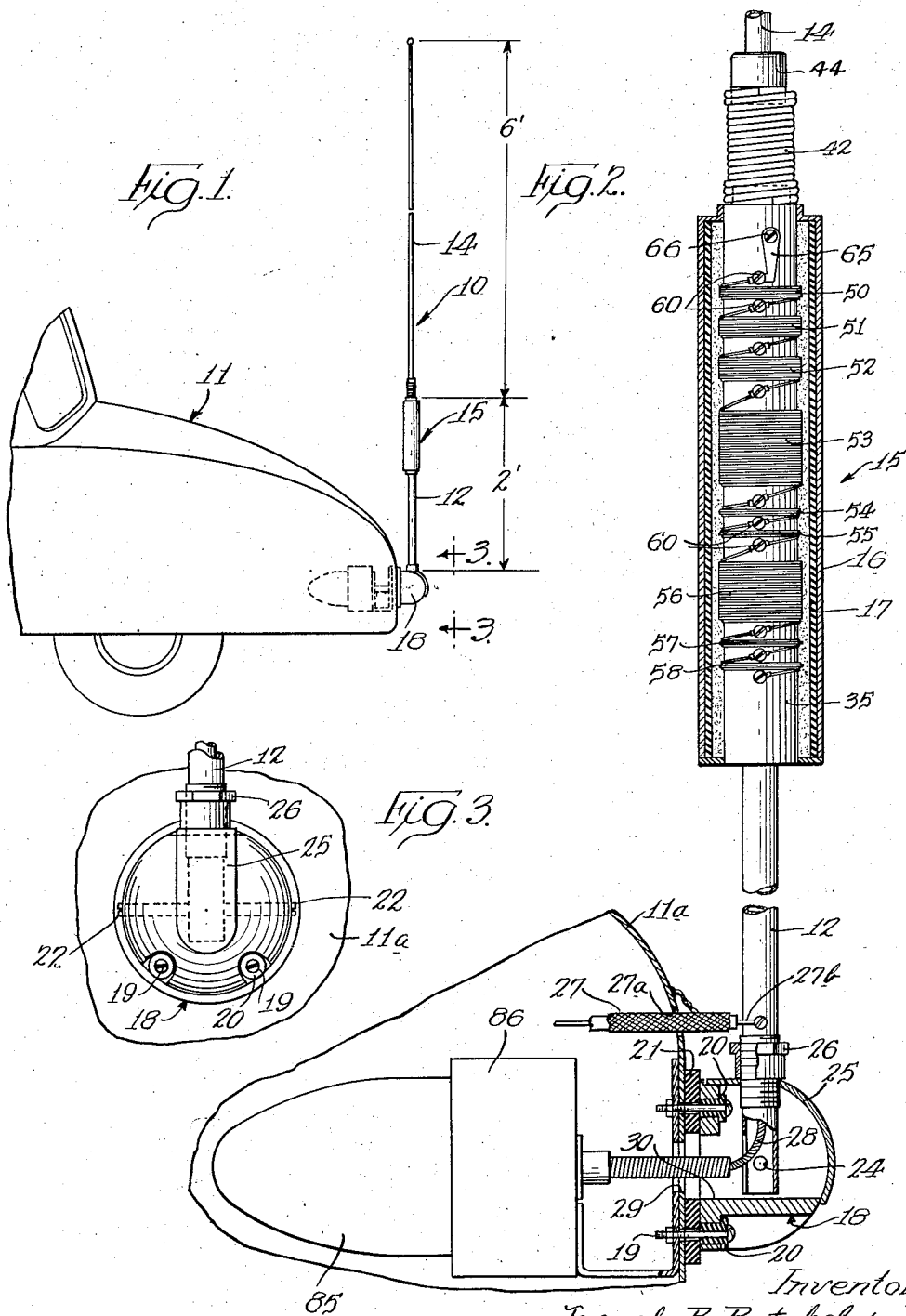
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ANTENNA FOR AUTOMOTIVE VEHICLES

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2 Sheets-Sheet 1



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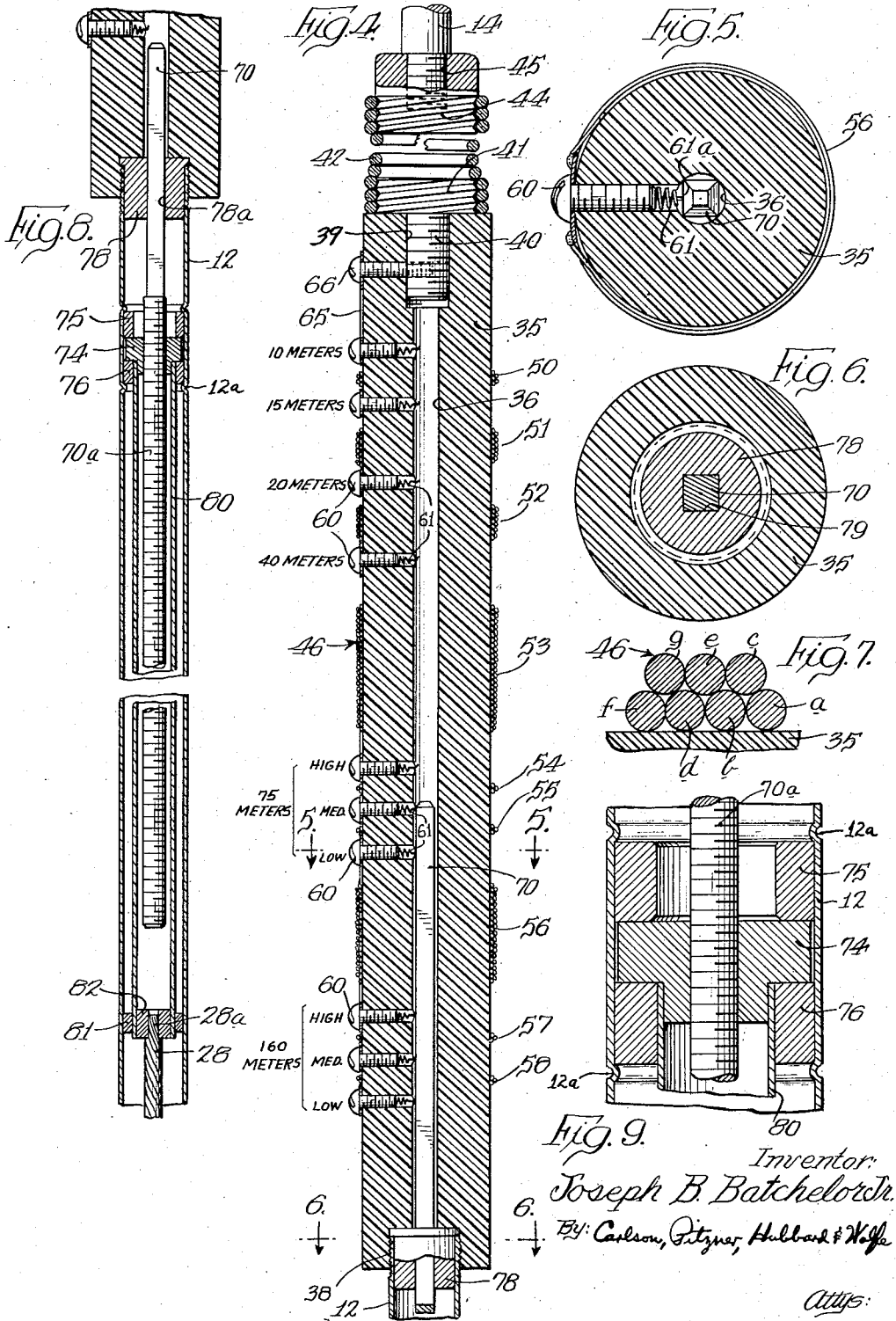
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## ANTENNA FOR AUTOMOTIVE VEHICLES

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2 Claims. (Cl. 343—714)

The present invention relates in general to antennas for transmitting radio signals, and in particular to adjustable inductance devices for "tuning" antennas used on automotive vehicles or other mobile equipment. The terms "automotive vehicles" is to be taken in its broadest sense inasmuch as antennas embodying the invention are advantageously employed on passenger automobiles, trucks, tanks, small boats and any other moving conveyance.

It is the general aim of the invention to provide an improved "loading" or "tuning" inductance for antennas used on automotive vehicles and which may be conveniently adjusted for substantially optimum performance in any of a number of frequency ranges, while at the same time being highly efficient in its operation and small in size as well as simple in construction.

Another object of the invention is the provision of such a device which may be adjusted for operation in different frequency ranges by means operable from a remote location, for example, the driver's seat of an automobile.

A further object is to create such an antenna in which a loading coil, progressively shorted for operation of the antenna in different frequency ranges, is so located as to give high transmission efficiency with regard to signal strength at distant points, yet having a coil and switching assembly of such compact size that it may be located in the position required without an unduly large and heavy supporting structure.

It is still another object to provide an antenna loading coil and switch means for adjusting the same which are not only small and compact, but which successfully prevent arcing across open switch contacts, present negligible capacitance between open switch contacts which might otherwise adversely affect the operation, and which drastically reduce the undesirable effects of mutual coupling between active and shorted coil portions.

Other objects and advantages of the invention will become apparent as the following description proceeds, taken in conjunction with the accompanying drawings, in which:

Figure 1 is a partial side elevation of a typical automotive vehicle having an antenna embodying the features of the invention mounted thereon;

Fig. 2 is an enlarged fragmentary view, partially in section, of the antenna shown by Fig. 1;

Fig. 3 is a detail elevation taken substantially along the line 3—3 in Fig. 1;

Fig. 4 is a vertical section showing a coil and switching assembly employed in the antenna;

Figs. 5 and 6 are horizontal sections taken substantially along the lines 5—5 and 6—6, respectively, in Fig. 4;

Fig. 7 is an enlarged fragmentary section corresponding to a portion of Fig. 4 and illustrating the manner in which the loading coil is wound;

Fig. 8 is a vertical section taken through the lower portion of the antenna; and

Fig. 9 is an enlarged view corresponding to a part of Fig. 8 and showing details of a lead screw and nut for adjusting the switching means.

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While the invention has been shown and is described in some detail with reference to a particular embodiment thereof, there is no intention that it thus be limited to such detail. On the contrary, it is intended here to cover all alterations, modifications, and equivalents falling within the spirit and scope of the invention as defined by the appended claims.

Referring now to the drawings, an antenna 10 constituting a preferred embodiment of the invention has been shown in Fig. 1 as mounted on an automotive vehicle 11 which in this instance happens to be a conventional passenger automobile. The antenna 10 may be viewed as made up of first and second elongated electrically conductive sections which may be designated as the base section 12 and the whip 14. Physically interposed between the base 12 and whip 14 is a loading assembly 15 which, as explained in detail below, includes an inductance element or "loading coil" connected in series with the two antenna sections. Assembly 15 may include a water-tight protective casing 16 coated on the inside with a suitable insulating material 17 to reduce the possibility of inadvertent electrical contact with the enclosed coil.

As shown best in Fig. 2, the base 12 of the antenna is made as a tubular steel member and is fixed in a vertical position to, while insulated from, the vehicle 11. For this purpose, a support fitting 18 is made fast to a panel 11a of the vehicle by a plurality of bolts or screws 19 which pass through insulating bushings 20 inserted into mounting holes within the housing. The screws 19 also pass through an insulating ring 21 which may be made of plastic or other suitable insulating material so that the fitting 18 and the antenna 10 supported thereby are both insulated from the vehicle itself. The lower end of the base section 12 is inserted vertically downward into the fitting 18 and retained by suitable means such as set screws 22 (Fig. 3) threaded through the fitting and engageable in openings 24 drilled in the base. An arcuate cover plate 25 through which the base 12 is inserted closes the top opening in the fitting 18 and is drawn tightly against the latter by an annular nut 26 engaged with threads cut on the base itself.

For feeding radio frequency energy to the antenna, a sheathed coaxial cable 27 leads from within the interior of the vehicle through an opening 27a cut in the panel 11a, the center conductor 27b being electrically connected to the base 12. The cable 27 may lead from a transmitter (not shown) located elsewhere in the vehicle. For a purpose to be described, a rotatable torque transmitting cable 28 is extended from within the vehicle through the insulating ring 21 and an opening 30 in the fitting itself.

Merely for purposes of illustration, it may be assumed that the antenna 10 is to be operated at signal frequencies in the 10, 15, 20, 40, 75 and 160 meter bands. As is well known, the antenna should, when operating in each band, approximate series resonance or substantially correspond to some odd multiple of a quarter-wave length. Under these conditions, maximum power is drawn from the transmitter because the antenna presents a low impedance and also matches the impedance of the connecting coaxial cable. It is possible to make the antenna approximately physically equal to an odd multiple of a quarter-wave length in the highest frequency range, i.e., in the 10 meter band, but as the operating frequency is lowered, the antenna presents a progressively higher capacitive impedance. Of course, it is impossible as a practical matter to make the antenna equal in physical length to a quarter-wave length in the lowest frequency range, i.e., in the 160 meter band. And with the antenna substantially less than a quarter-wave length in the lower frequency ranges, the capacitive impedance which it presents is so very high that little power is drawn from the transmitter, and still less is radiated into space.

It is well known that operation at the lower frequencies can be obtained by placing a coil in series with the antenna which has an inductance of proper magnitude to substantially resonate with the antenna's capacity. A different value of inductance is needed for operation in each frequency range, and in some cases for operation in different portions of one frequency range. This has led in the past to the use of a plurality of coils which might be substituted one for the other, or suitable coils having taps or contacts which could be adjusted to short out different portions.

In these prior arrangements, it was necessary for the operator to stop the vehicle, disembark, and then either substitute coils in the antenna or adjust the tap of a coil in the antenna, the latter steps often requiring assembly and disassembly of parts by the use of tools.

Before considering that aspect of the invention which permits adjustment of a loading coil from a remote location and thus eliminates the inconveniences referred to, it will be appropriate to treat a second feature of the invention which concerns the physical location of a loading coil longitudinally of the antenna. It will be helpful to note first that all radiation in the communication frequencies is both electrostatic and electromagnetic in nature. The electrostatic radiation is commonly known as the "ground wave" and takes place through minute capacitive coupling between the antenna and foreign objects, such as receiving antennas, located at remote points. The electrostatic or "ground wave" radiation is normally effective for only short distances in the order of 3 to 15 miles and it is produced as the result of voltage variations on the antenna giving rise to a radiating electrostatic field. The electromagnetic radiation, on the other hand, is produced by current flow within the antenna generating a changing magnetic field which is radiated in space. This is commonly called the "sky wave" and it is effective for extremely great distances depending upon the atmospheric conditions.

In the loading coil for the antenna were located at its very base, or perhaps inside the body of the vehicle, it is possible to "tune" the antenna to series resonance and thus properly load the transmitter. However, the resulting current flow is primarily confined to the loading coil and is shielded by the vehicle body so that only a high voltage is present, for practical purposes, on the exterior portion of the antenna. This produces then, a relatively strong electrostatic radiation or "ground wave," and a correspondingly weak electromagnetic radiation or "sky wave." This has been proven by actual tests and found unsatisfactory for transmission of signals over appreciable distances.

On the other hand, if the loading coil is interposed and connected in series with two antenna sections, the coil being located in the mid portion of the antenna or near the top thereof, the upper portion of the antenna, for a given over-all length, becomes so short that it has very little capacity. As a result, in order to resonate that capacitive reactance an extremely large inductive loading coil must be employed. Such a large, and therefore relatively heavy, coil located near the top of the antenna has been found to present structural difficulties. Either the base must be made unduly large and heavy, or risk of breaking the antenna is present.

If the loading coil is placed externally of the vehicle but at the very bottom of the antenna, substantially the same result is experienced as explained above in the case of the loading coil being located within the vehicle. Standing voltages on the antenna produce a strong electrostatic or ground wave but current flow is so confined to the lower portion of the antenna, which is capacitively coupled directly back to the vehicle, that a relatively weak electromagnetic wave is produced. If the loading coil is placed in the upper portion or center of the antenna then it must be of higher inductance and since substantially perfect resonance is not readily obtainable due

to the extremely small capacity of the shortened top antenna section, smaller currents flow in the upper section of the antenna and thus produce a relatively weak electromagnetic wave.

Accordingly, it has been my discovery proven by experiments that an electromagnetic or "sky wave" of maximum strength, for a given antenna length and transmitter power, may be obtained by locating the inductive loading coil approximately mid-way between the center of the antenna and its lower end. Stated another way, I have found that appreciably better radiation for long distance transmission can be obtained by making the combined length of the antenna base section and the loading coil approximately one-third as long as the upper antenna section, e.g., by making the base 12 and loading assembly two feet long and the whip 14 six feet long.

It has been my discovery that in order to obtain high transmission efficiency, the capacitive coupling between the upper portion of the antenna and the base or vehicle body must be maintained very low in relation to the capacity between the upper antenna portion and "free space." In other words, stray capacity back to the vehicle body or the antenna itself which "shunts" radio frequency energy must be minimized in order that substantially all of the radio frequency energy will be radiated, i.e., transmitted through the capacitance between the antenna and free space. For no matter how perfectly the antenna is tuned to resonance and how well it loads the transmitter, it is the strength of the transmitted signal which determines the success of the antenna.

In putting this principle to advantageous use, a loading coil assembly is constructed in a manner such that the stray capacity between its adjacent turns is minimized, and switching means are provided which present very little capacity across open contacts. These two features result in an antenna having a very small stray capacity between its whip and either the base or the vehicle, so that a greater proportion of the radio frequency energy is transmitted into free space.

In accordance with the invention, there is provided a loading assembly which due to its relatively small size and weight, is conveniently located as described above, and which affords adjustment of the effective value of the loading inductance by means operable from a remote location. In accomplishing this, an elongated hollow coil form 35, having a central passage 36 therethrough, is physically interposed between the base section 12 and the whip section 14 (Figs. 2 and 4). As illustrated in the drawings, the coil form 35 may be cylindrical in shape and may be made of any suitable insulating material such as a ceramic. For attachment of its lower end to the upper portion of the base section 12, the coil form 35 is counterbored and tapped at 38 to be screwed onto threads cut in the upper extremity of the base section 12 (Fig. 4). Similarly, the upper end of the coil form 35 is counterbored and tapped at 39 to receive the threaded shank 40 of a plug 41 having large spiral threads thereon. For attaching the whip section 14 so that it may deflect without damage if it should strike an overhead object, resilient means in the form of a heavy helical spring 42 are employed. The spring has its turns in thread-like engagement with the plug 41, and receives at its upper end an externally threaded plug 44 which is internally tapped as at 45 to receive the threaded lower end of the whip section 14. The base 12, coil form 35, and whip 14 are thus all supported in vertically upright, coaxial relation, the latter having freedom to deflect owing to the resiliency of the spring 42.

For providing the necessary compensating inductance in various ones of the frequency ranges, a coil designated collectively by the character 46 is wound on the coil form 35. For optimum performance, the coil is created from a continuous conductor, or a number of conductors connected in series, which is wound in multiple layers

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"bank" formation. Fig. 7 illustrates the manner in which the coil is bank-wound. As there shown, a first turn *a* is wrapped about the coil form 35 and adjacent thereto a second tube *b*. The next turn *c* is wound on top of and between the turns *a* and *b*, lying in the channel formed thereby. After the turn *c* is completed, the wire is crossed axially along the coil form and wrapped in a fourth turn *d* directly in contact with the coil form. The wire is then crossed retrogressively to form the fifth turn *e* which lies on and between the turns *b* and *d*. Upon completion of the turn *e*, the wire is led axially along the coil form to create the turn *f*, and then doubled back to form the turn *g* lying over and between the turns *d* and *f*. The wire is, of course, enamel or otherwise insulated and the pattern illustrated by Fig. 7 is repeated over and over to create the entire coil 46.

Several advantages have been found to result from the coil which is bank-wound as described. Such winding lowers the capacitive coupling between adjacent turns, i.e., the stray capacity across the coil. As explained above, this contributes to the elimination of shunting energy back to the base 12 or the vehicle 11, so that more energy is radiated from the whip into free space. Secondly, bank-winding increases the mutual inductance between adjacent turns of the coil so that the coil has a higher inductance for fewer turns, as contrasted with a helical coil, thereby permitting it to be smaller in size. Moreover, fewer turns mean that a shorter length of larger diameter coil wire may be used in the available space so that copper losses, i.e.,  $I^2R$  losses, are considerably reduced. As a result of the bank-winding arrangement, therefore, a relatively small coil provides a relatively high inductance with little stray capacity and results in efficient operation since copper losses are considerably reduced.

As illustrated in Figs. 2 and 4, the composite coil 46 is made up of a plurality of individual coil portions 50—58 which are spaced axially along the coil form. The several individual coil portions spaced apart axially may be formed by a single conductor or by a plurality of individual conductors which are connected together in series relation. As noted, each of the coil portions 50—58 is bank-wound. Merely by way of example, the coil portion 50 may present sufficient inductance to correctly load a transmitter for operation in the 15 meter band, the antenna otherwise properly loading the transmitter for operation in the 10 meter band. Correspondingly, the additive inductance of the coil portions 50 and 51 is made of the proper value to load the transmitter for operation in the 20 meter band. The sum of the inductances provided by the coil portions 50, 51 and 52 is made of the proper value to resonate the antenna for operation in the 40 meter band. Collectively, the inductance of the coil portions 50—53 is proper to resonate the antenna for operation in the 75 meter band. Likewise, the sum of all of the inductances provided by the coil portions 50 through 58 properly compensates for operation of the antenna in the low portion of the 160 meter band. It will be observed that the coil portions 57 and 58 permit adjustment for operation in either the high, medium or low portion of the 160 meter band, while the coil portions 54 and 55 likewise provide for compensating adjustment within the 75 meter band.

The coil form and coil are maintained relatively small in over-all diameter while provision is made for progressively shorting out the coil portions 50—58 to tune the antenna for operation in any of the several frequency bands indicated by way of example. For this purpose, a plurality of taps are electrically connected at spaced points along the coil, and more particularly at junctions in the coil between the successive coil portions. As shown in Figs. 2, 4 and 5, such taps are created by electrically conductive screws 60 which are threaded into a corresponding plurality of radial holes drilled through the coil form 35. The heads of the sev-

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eral screws 60 are drawn against and electrically connect with the coil conductor in the region where it progresses from one coil portion to another, as shown particularly in Fig. 2. The taps preferably include resilient brushes to facilitate switching as described below. In this instance, a small spring 61 of phosphor bronze or the like is suitably soldered or welded to the inner end of each screw 60, the inner, free end 61a of the spring projecting into the passage 36. Electrical connection of the base section 12 to the lowermost spring 61 and screw 60, therefore, leaves all of the coil portion 50—58 in series, while electrical connection of the base 12 to all of the springs 61 and screws 60 shorts out each of the respective coil portions 50—58, leaving the antenna adjusted for proper operation in the 10 meter band with no compensating inductance.

The composite coil 46 is electrically interposed or connected between the base section 12 and the whip section 13. For this purpose, a conductive metal strap 65 (Fig. 2) is engaged by the top tap screw 60 and a screw 66 which is threaded through the coil form 35 for locking engagement and electrical contact with the shank 40 of the plug 41 (Fig. 4). The plug 41 is, of course, electrically connected with the whip 13 through the spring 42 and the plug 44.

For the purpose of progressively engaging the coil taps here formed by the springs 61 and screws 60, a conductive, preferably non-magnetic plunger 70 is disposed within the passage 36 of the coil form 35 with freedom to slide axially therein. The plunger 70 is always electrically connected to the base section 12 regardless of its position, as will become apparent from the following paragraphs. As its upper end is moved upwardly, it successively engages the coil taps and therefore successively shorts out the coil portions 58 through 50. With the plunger 70 in the position illustrated by Fig. 4, the coil portions 58, 57, 56 and 55 are all shorted and the antenna is adjusted for operation in the high region of the 75 meter band.

It will be observed that the cooperative arrangement of the coil taps projecting inwardly through the coil form and the plunger 70 slidable axially within the coil form results in an assembly which is relatively small in diameter. Other advantages accrue from the arrangement described. By spacing the coil portions 50—58 axially apart on the coil form 35, the coil taps formed by the screws 60 and springs 61 are likewise spaced axially apart. Thus, with the upper end of the plunger 70 engaging a given one of the springs 61 it still is considerably spaced from the next tap spring. For this reason, there is very little capacitive coupling between the upper end of the plunger 70 and the next coil tap. Viewing the plunger 70 and each of the springs 61 as switch contacts, therefore, the switch contacts have negligible capacity when open. Thus the switching arrangement minimizes capacitive shunting from the whip and active portions of the coil back to the base 12. This, as explained above, promotes greater efficiency by eliminating or minimizing shunting of energy back to the base, to the end that most of the radio frequency energy is radiated from the whip into free space.

Additionally, experience has shown that with the application of only 50 watts of radio frequency energy to an antenna of this type, the voltage becomes so high that it will arc approximately one-half inch. I have found it necessary that open switch contacts be separated by something in excess of one-half inch. In the present arrangement, the upper end of the plunger 70 is always separated from the next free coil tap by a considerable distance so that the likelihood of arcing is substantially eliminated. Finally, with the coil portions spaced apart axially on the coil form 35, there is only relatively small mutual coupling between adjacent portions. This becomes important when one considers the effect of shorted coil portions on unshorted coil portions. For example,

as viewed in Fig. 4, the shorted coil portion 53 has relatively little mutual coupling to the active coil portion 54 due to the spacing therebetween. Thus relatively small circulating currents are set up in the coil portion 53 and the power loss in the latter coil portion, which would subtract from the efficiency of the antenna, is minimized.

In order to shift the plunger 70 to any of its axial positions, i.e., to selectively short out successive ones of the coil portions 50—58, motion transmitting means operable from a remote location are provided. In the present instance, the lower end portion 70a of the plunger 70 is circular in shape and externally threaded. The upper end is preferably rectangular in cross section to facilitate electrical contact with the springs 61 and to prevent rotation of the plunger within the coil form. Cooperating with the externally threaded lower plunger portion 70a is an internally threaded nut 74 which has a sliding, journaled contact with the inner surface of the tubular base section 12. The nut 74 is restrained against axial movement within the base 12 by a pair of retaining rings 75, 76 (Fig. 6) axially restrained inside of the base 12 by suitable means such as inturned beads 12a. It will thus be seen that rotation of the nut 74 in opposite directions serves to move the plunger 70 up or down within the coil form 35. To prevent rotation of the plunger 70, it is passed through a bushing 78 seated in the upper end of the base 12 and having a rectangular hole 78a therethrough mating with the cross section of the plunger 70 (Figs. 6, 8 and 4).

In order to effect rotation of the nut 74, it is rigidly socketed into the upper end of an auxiliary tube 80 which is coaxially disposed within the base 12 and which coaxially surrounds the plunger portion 70a. The tube 80 is journaled at its upper and lower ends by the retaining ring 76 and a bearing ring 81, respectively. Disposed in the lower end of the tube 80 is a plug 82 having a non-circular opening therethrough which receives a non-circular or flattened end 28a of the cable 28, thus effecting a driving connection between the cable and the tube 80.

The cable 28 as shown in Fig. 2 extends into the interior of the vehicle 11 and may be rotated by any suitable means such as a hand crank, or power means such as a motor. As here shown in Fig. 2, an electric motor 85 is located inside the vehicle and serves to drive the cable 28 through a suitable speed reducing gear box 86. The motor may be controlled for starting and stopping and as to its direction of rotation by appropriate switch means (not shown) located, for example, at the driver's seat. Through this arrangement, therefore, the operator of mobile radio transmitting equipment carried by the vehicle equipped with the antenna 10 may adjust the latter for operation in any one of a number of frequency ranges simply by controlling the rotation of the cable 28 and thus vertically positioning the plunger 70 so that it engages a proper number of the tap springs 61 to short out the proper ones of the coil portions 50—58. Yet, despite the convenience afforded by this inductance-adjusting arrangement, the inductive coil and switch means are themselves so very compactly constructed that they may be mounted, as indicated, physically interposed between top and bottom antenna sections. An especially high value of inductance is realized for a given size of

the coil form and length of coil wire by bank-winding the wire to create the composite coil 46. Such bank-winding substantially reduces capacitive coupling between adjacent coil turns, at the same time increasing mutual inductance between turns so that the over-all inductance of the coil portions is high relative to their physical size. The particular switch means consisting of taps projecting inwardly from the coil to the interior of the coil form and cooperating with an axially movable plunger, results in a switching means which leaves the coil assembly small in diameter but yet which presents negligible capacitance between open switch contacts, and spaces those open contacts sufficiently to prevent arcing when the antenna is driven with relatively high power.

I claim:

1. For use with an antenna having two conductive sections, one of said sections being hollow and rigid and having means for attaching the same in a vertical position to and insulated from an automotive vehicle, the combination comprising a hollow elongated coil form of insulating material rigidly fastened in vertical position to the upper end of said one section, spring means fastening the other of said antenna sections in vertical position to the upper end of said coil form, a coil comprising wire bank-wound on said coil form in serially connected portions spaced apart axially of the coil form, means electrically connecting the extremities of said coil respectively to said two antenna sections, a plurality of coil taps connected respectively with the wire between successive ones of said coil portions and extending inwardly to the interior of said coil form, a conductive plunger having electrical connection with said one antenna section and slidable axially within said one section up into said coil form to contact said taps and successively short out said coil portions, means rotatably disposed within said one antenna section and connected with said plunger for shifting the latter axially, and a flexible drive connection leading from the exterior of said one section to said rotatable means for turning the latter.

2. For use with an antenna mountable on an automotive vehicle, the combination comprising a base section of tubular metal, a hollow cylindrical coil form of insulating material and means fixing it in coaxial relation to one end of said base section, a coil made up by a conductor bank-wound upon said coil form in series connected axially spaced portions, a plurality of taps extending through said coil form and electrically connected to said coil intermediate the successive portions thereof, a conductive rod slidably extending through said coil form and adapted to engage said taps, the lower end of said rod projecting into said hollow antenna section and having threads thereon, a nut disposed within said hollow antenna section and threadably engaged with the lower end of said rod, and means including a flexible element extending from the interior of the exterior of said hollow section for relatively rotating said nut and rod, so that the rod may be moved axially to progressively contact said taps and short out successive ones of said coil portions.

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