

[54] **ADJUSTABLE CENTER LOADED
ANTENNA ARRANGEMENT**

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[58] Field of Search 343/745, 750, 703, 749, 715, 343/860

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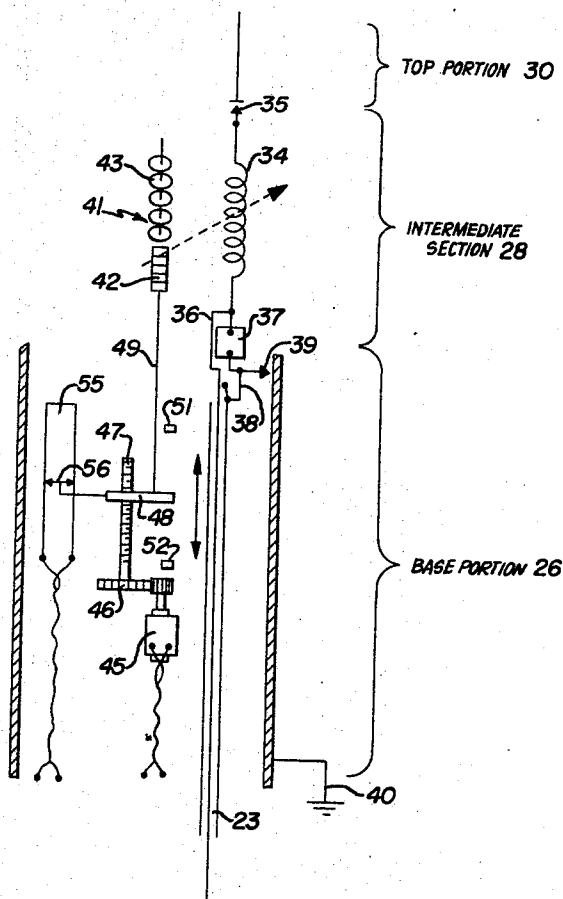
Primary Examiner—Eli Lieberman

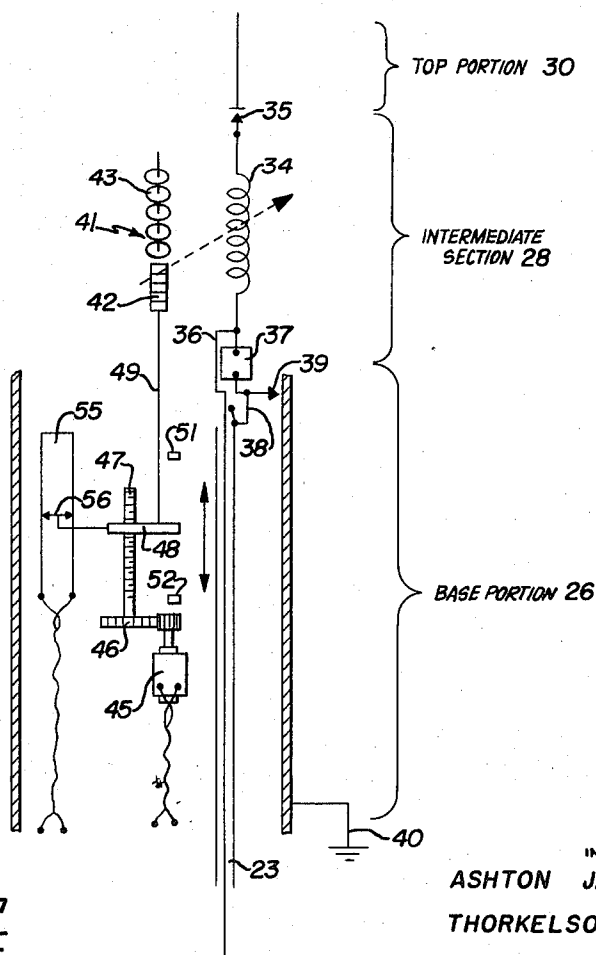
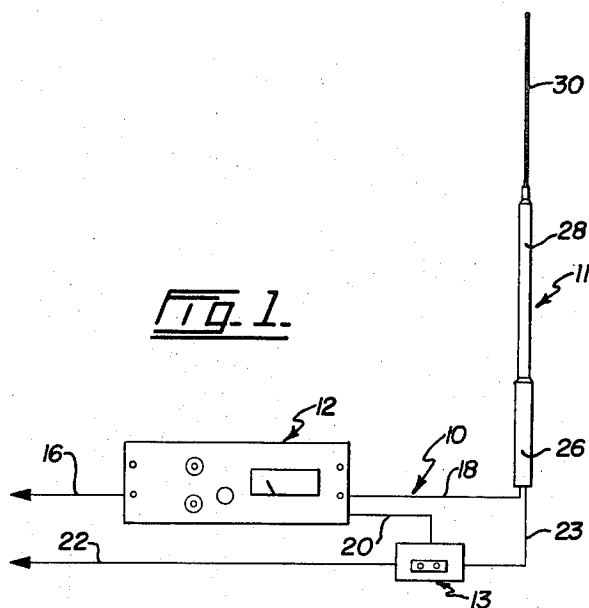
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[57] **ABSTRACT**

A center-loaded antenna arrangement having a fixed loading coil in a whip antenna, and a tuning core mounted for movement through and out of the coil, said core having a ferrous section and an inductor ring section. Suitable connecting means connects an end of the coil to a radio ground and to a radio transmitter or receiver through a R.F. transmission line. This connecting means is preferably connected to the radio ground through an impedance matching device which couples the coil to the transmitter or receiver.

9 Claims, 7 Drawing Figures





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Fig. 3.

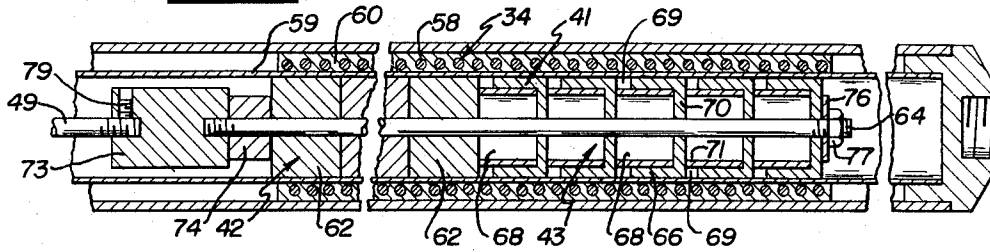


Fig. 4.

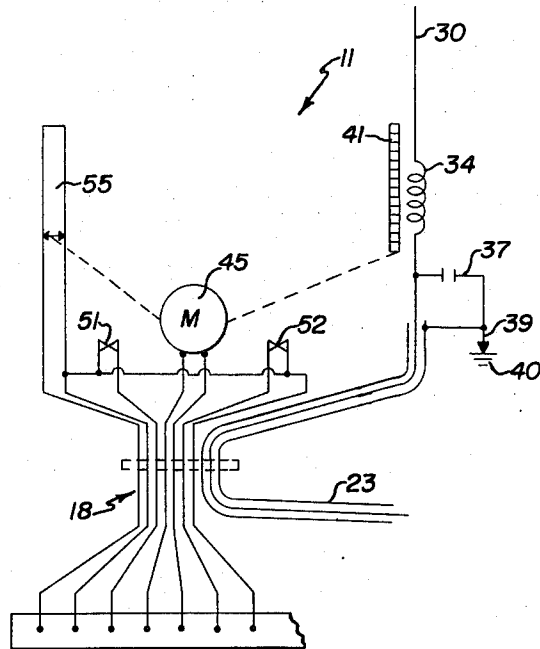
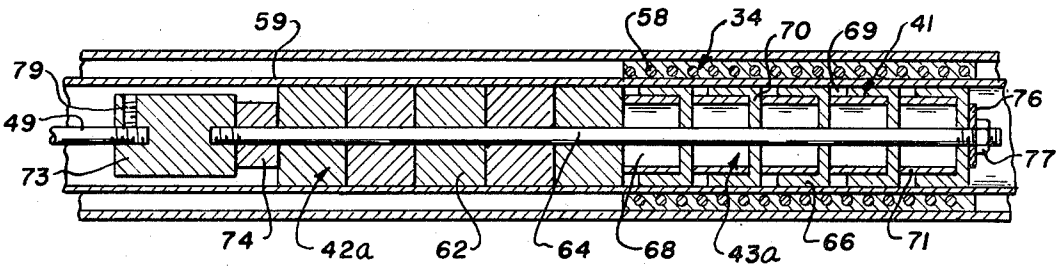


Fig. 7.



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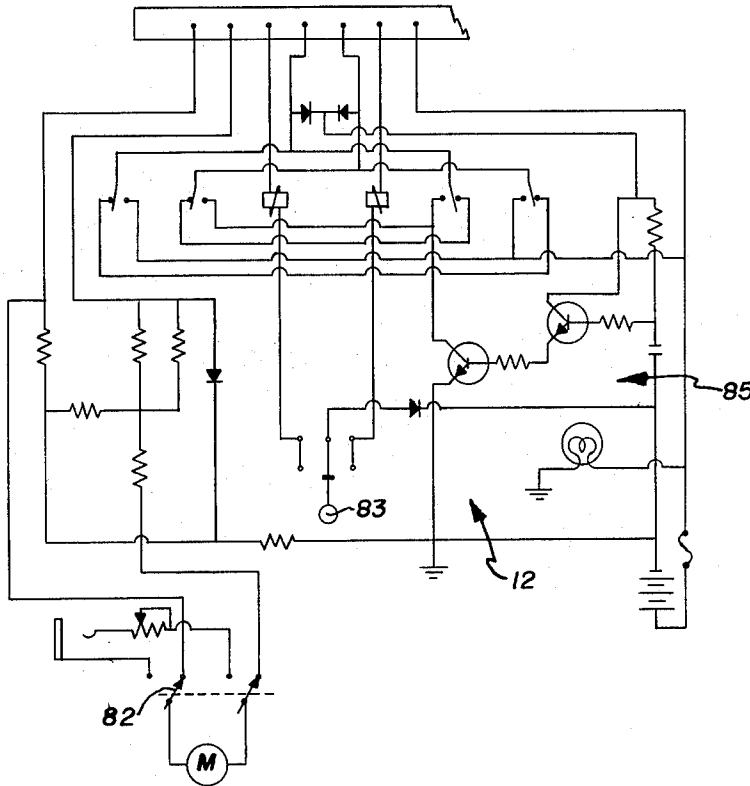


Fig. 5.

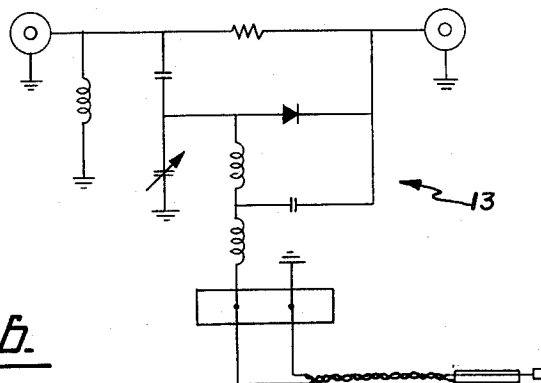


Fig. 6.

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ADJUSTABLE CENTER LOADED ANTENNA ARRANGEMENT

BACKGROUND OF THE INVENTION

There is a great need for a center-loaded mobile antenna which is of small dimensions, light in weight (particularly for use in aircraft), efficient over a large frequency range, permits coupling to a transmitter over a shielded, coaxial cable with very low voltage standing wave ratio (VSWR), is tunable accurately from a remote location, is completely waterproof, and rugged enough to withstand reasonable abuse and high air speed. There is no antenna on the market that meets all of these requirements.

One of the main difficulties in designing an antenna having these features is to achieve a constant base resistance over its entire tuning range. This is necessary to avoid numerous matching changes between the antenna and the transmission line connected thereto to accommodate different frequencies. It is also necessary to attain accurate tuning and matching of the antenna to avoid high standing waves on the transmission line with the resultant losses. More important than the losses from standing waves, however, is the effect of reactive transmission line loads on transmitters, particularly single sideband transmitters which employ linear amplifiers. This reactive load can easily reduce the output power of a single sideband (SSB) transmitter by 50 percent or more and introduce severe distortion in the linear power amplifier.

The base resistance of a center-loaded whip antenna is dependent mainly on two factors, (1) the total physical length of the antenna versus the frequency of operation, and (2) the "Q" or quality factor of the centrally located loading coil.

SUMMARY OF THE INVENTION

This invention relates to adjustable center-loaded antenna arrangements or systems particularly suitable for vehicular operation.

An adjustable center-loaded antenna arrangement according to the present invention comprises a bottom portion, a hollow intermediate portion connected at one end to the base portion, and a top or outer portion connected to the opposite end of the intermediate portion. A loading coil is fixedly mounted in the intermediate portion and has one end to be connected to a radio frequency transmitter and an opposite end connected to the top portion. A tuning core is mounted in the intermediate portion for movement through and out of the coil, this core having a high permeability ferrous section axially aligned with an inductor section.

The total physical length of the antenna is set by practical consideration, and around 9 feet has been found to be a practical length for many purposes. The radiation resistance of an antenna of this length at a frequency of 2 MHz is approximately 1.5 ohms, and at 8 MHz it is approximately 3.5 ohms. The resistance of this whip antenna would be 1.5 ohms, plus the resistance of the loading coil, at 2 MHz and 3.5 ohms, plus the resistance of the loading coil at 8 MHz.

The major portion of the resistance of the antenna is the loading coil resistance, while the radiation resistance is usually relatively small. By using the highest quality material available in the ferrous section of the core, an optimum wire size and turns spacing, the "Q" of the loading coil is maintained at a high level at the lower frequencies, in which condition the ferrous section of the core is in the coil. Toward the high frequency end of the tuning range, the inductor ring section is moved into the coil and the ferrous section is moved out. At the highest frequency all the ferrous section is out of the coil and the entire inductor ring section is in it. The inductor section is made up of a plurality of spaced copper inductor rings. The size of these rings and the gaps between them are determined to give an overall effect of a steadily rising loading coil "Q" from the high frequency end of the tuning range to the low frequency end.

The "Q" of the loading coil of the example antenna system set out above rises almost linearly from 8 MHz down to 2

MHz, resulting in a base resistance centering at 32 ohms. The tuning coil is connected by a coaxial cable to the transmitter. In this example, a fixed matching network is used between the 52 ohm transmission line or cable and the base of the antenna to match down from 52 to 32 ohms. The VSWR on the 52 ohm transmission line with this antenna properly installed is typically 1.1:1 or lower over the entire frequency range of 2 to 8 MHz.

With this antenna, it is possible to attain a substantially constant RF antenna base resistance over a wide range of frequencies. This is accomplished by the specific core construction and association with the tuning coil and the connection of the end of the coil to a radio ground through an impedance matching device for coupling it to a radio transmitter or receiver through a RF transmission line. The core includes a ferrous section and an inductor ring section. A high "Q" material is used in the ferrous section, the rings are made of highly conductive material, and the length, thickness and spacing of said rings are selected to produce the desired change in the inductance and "Q" of the tuning coil.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 diagrammatically illustrates an example of antenna arrangement or system in accordance with this invention,

FIG. 2 is a diagrammatic view of the interior of the antenna of this system,

FIG. 3 is an enlarged sectional view through the loading coil and tuning core of the antenna,

FIG. 4 is a wiring diagram of the antenna,

FIG. 5 is a wiring diagram of an example control unit in this system,

FIG. 6 is a wiring diagram of an example SWR detector used in the system, and

FIG. 7 is a view similar to FIG. 3, illustrating a preferred form of loading coil and tuning core for the antenna.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Some values are set out in the wiring diagrams, but it is to be understood that these are for the purpose of illustration only, and are not intended to be used in a limiting sense.

Referring to FIG. 1 of the drawings, this depicts an adjustable center-loaded antenna arrangement or system 10 in accordance with this invention, this system including an antenna 11, a control unit 12, and a VSWR sensor 13. The control unit is connected to a suitable source of power, not shown, by wires 16, and to antenna 11 by a multiple wire cable 18. This control unit is also connected to the sensor unit 13 by wires 20. The SWR sensor unit is connected by a coaxial cable 22 to a radio transmitter or receiver, not shown, and by a coaxial cable 23 to antenna 11.

The antenna 11 includes a bottom portion 26, usually made of aluminum, an intermediate section 28, preferably made of fiber glass or any other suitable non-conducting material, and an outer or top portion, 30 usually made of a flexible wire enclosed in fiber glass. The antenna portions 26, 28 and 30 are permanently or removably connected to each other in any desired manner. The terms "bottom" and "top" are used for descriptive purposes only since the antenna functions in any position, such as vertical, horizontal, upside down, and the like.

Referring to FIG. 2, a center-loading coil 34 is fixably mounted within intermediate portion 28 and is connected at one end by means of spring contact 35 to top portion 30, and at the other end by a wire 36 to the center conductor of coaxial transmission line 23. One side of an impedance matching device, such as a capacitor 37, is connected by said wire 36 to coil 34, and the other side of said capacitor is connected by a wire 38 to the outer shielding of the line 23. At the same time, wire 38 is connected by means of spring contact 39 to the inside of the aluminum bottom portion 26. This bottom portion is connected to the radio ground, as indicated at 40 in FIG. 2.

A tuning core 41 is mounted for movement into and through coil 34, and this core is made up of a ferrous section 42 and an inductor ring section 43. The ferrous and ring sections 42 and 43 are of such length and are positioned relative to each other so that when one section is completely within the coil, the other section is completely outside it, and yet portions of both sections can be in the coil at the same time. For example, the section lengths may be such that both will fit within the coil at the same time, or each section may be substantially the same length as the coil. FIG. 3 shows the ferrous section 42 and the inductor ring section 43 of such lengths that both can fit in coil 34 at the same time, whereas FIG. 7 shows a ferrous section 42a and a ring section 43a, each of which is substantially the same length as coil 34.

Power means is provided for moving core 41 relative to coil 34. In this example, there is mounted in bottom portion 26 of the antenna a reversible electric motor 45 which turns through gears 46 a worm or screw 47 upon which a nut 48 is threaded. A stiff connector or rod 49 extends between and is connected to core 41 and nut 48. Limit switches 51 and 52 are provided at the ends of the path of travel of nut 48 so as to be engaged by the latter in order to prevent core 41 from being moved too far in either direction relative to the loading coil. Suitable means is provided for indicating the linear position of the tuning core, and this may be in the form of a sliding resistance wire bridge having a slide 56 and mounted in base portion 26, said slide being connected to and moved by nut 48. The resistance of the bridge is proportional to the linear position of the tuning core and indicated by a meter on the control panel.

FIG. 3 illustrates coil 34 and core 41. Coil 34 is made up of a wire 58 space wound on a thinwall fiberglass tubing 59. The wire is embedded in a resinous coating 60 which may be an epoxy resin. The ferrous section 42 of the core is made of short cylindrical ferrous slugs 62 which are resiliently held together under tension by rod 64 formed of a non-conducting material, such as teflon. Although the ferrous section may be in the form of a single ferrous slug, it is preferably made up of a plurality of slugs, as shown. The slugs are made of compressed powdered iron. The material of the slugs is one displaying the highest permeability with the lowest losses over the frequency range for which the antenna is designed. Rod 64 extends from ferrous section 42 to inductor ring section 43. This section 42 consists of copper conductor rings 66 mounted on rod 64 and separated from each other by non-conducting spacers 68 to form gaps 69 therebetween. These gaps are of sufficient width to prevent short circuiting between adjacent rings. Each conductor ring 66 is preferably in the form of a cup having a base 70 through which rod 64 slidably extends. Each spacer 68 is a sleeve fitting within the ring or cup 66 and bearing at one end against cup base 70, and at its opposite end projecting beyond the ring, as indicated at 71, to bear against the outer surface of base 70 of the next adjacent base, as clearly shown in FIG. 3. The complete core consists of coupling 73 to which rod 64 is attached, a non-conducting spacer 74 between said coupling and the end slug 62, ferrous slugs 62, spacers 68, and copper inductor rings 66. The right hand slug 62 bears against the end of the adjacent spacer sleeve 68, and the right hand ring or cup 66 bears against a non-conducting stop or disc 76 which is carried by rod 64 and is held in place by a nut 77 threaded on the end of said rod. A set screw 79 in coupling 73 secures core 41 to rod 49.

The size and spacing of the turns of wire 58 of coil 34 are determined to provide the correct inductance for the frequency range desired and also with regard to the amount of RF power for which the antenna is designed. As one example of an antenna designed to cover 2-8 MHz and with a maximum power rating of 120 watts peak power, 196 turns of No. 22 B & S gauge wire wound on a 13/16 inch round coil form and evenly spaced to a total length of 7 inches have been used. These dimensions are illustrative only, and the dimensions must be established on a case by case basis.

The optimum number, diameter and wall thickness of the inductor rings are dependent on several factors, the major ones being:

a. Maximum Tuning Effect

The inductor ring operates in accordance with Lenz Law which shows that the current induced in the inductor ring has 180° phase difference to the current in the coil. The flux in the inductor ring opposes the flux in the main coil and reduces the total inductance of the coil. This has the effect of increasing the resonant frequency of the antenna. In order to attain the maximum effect it is necessary that the outer diameter of the inductor ring closely approximates the inner diameter of the coil. In other words, the space between the inductor ring and the coil must be kept to a minimum consistent with providing the required insulation between the two.

b. Minimum Electrical Losses in the Inductor Rings

If the inductor ring extends over a considerable part of the total length of the coil a capacitively coupled circuit is presented across the axial length of this portion of the coil and across the high R.F. voltage existing therein. This results in an unwanted and wasteful current being set up through the length of the inductor ring which lowers the voltage across the coil and reduces its effectiveness. In order to minimize this loss it is necessary to divide the inductor ring into a number of sections. The number of divisions used is limited only by the added complexity and cost of the design. In practise, it has been found that an acceptable compromise is to reduce the length of the individual inductor ring section to a figure not exceeding its diameter.

c. Minimum Capacitive Coupling Between Sections

In order to further reduce the loss current set up through the series of inductor rings it is desirable to reduce the wall thickness of the rings as much as possible and thus reduce the electrical capacity between rings. The point beyond which the thickness cannot be effectively reduced is reached when the current carrying capacity of the ring becomes insufficient and/or the mechanical strength of the ring is insufficient. As an example a wall thickness of 0.001 in. has been found to be satisfactory in this antenna.

d. Mechanical Flexibility

In order to sustain bending and impact strains in mobile operation it has proved advantageous to divide the length of the inductor ring into many sections flexibly attached to each other. This is accomplished automatically when the conditions outlined in a, b, and c above are complied with.

When ferrous section 42 of tuning core 41 is moved into coil 34, it has the effect of increasing the inductance of the coil and lowering the frequency. When inductor section 43 is moved into the coil, the inductance is decreased and the frequency is increased.

The intermediate portion 28 of the antenna has a certain amount of flexibility, and the making of the ferrous section 42 in a plurality of ferrous slugs spring loaded together provides a degree of flexibility in this section and helps to avoid mechanical damage from impact and bending of the whole structure due to inertia of air drag loading.

Control unit 12 includes a tuning meter 81, a two-position control switch 82, and a motor control switch 83. When switch 82 is in one position, meter 81 is connected to the resistance bridge 55 of the antenna and indicates the linear position of the tuning core 41 relative to coil 34. When this switch is in its other position, it connects the meter to the VSWR sensor unit 13 to indicate the ratio of reflected power to forward power in the coaxial transmission line 23, and is used to indicate the exact adjustment at which the minimum reflected power is attained as a result of the tuning of the antenna.

The VSWR sensor unit, which is of a type well known in the industry, contains the necessary circuitry to detect forward or backward power in the coaxial transmission line to provide an indication on the meter in the control unit.

The coaxial transmission line 23 is terminated in antenna 11 in such a way as to match the impedance of the antenna to that of the coaxial transmission line. The values of capacity and inductance introduced to the antenna circuit by means of the tuning element are critically designed to provide an apparent constant electrical impedance at the antenna connection so that uniform power transfer between the coaxial transmission

line and the antenna through the coupling device is attained over the entire tuning range.

An amplified R/C circuit, indicated at 85 in FIG. 5, is placed in circuit with motor 45 and switch 83 to provide a high starting resistance when the control switch is operated. This results in the motor starting at a slow speed and increasing gradually to full speed, thus facilitating fine positioning of the tuning core in the loading coil.

The above system readily lends itself to full automatic tuning of the antenna. In this case, the sensor will detect whether the antenna appears inductively or capacitively reactive and thence through appropriate electrical circuiting and switching devices will cause the motor to so adjust the position of the core relative to the tuning coil to correct the capacitive/inductive imbalance and thus tune the antenna automatically to the frequency of the R.F. output of the transmitter.

Some of the advantages of the present center-loaded antenna arrangement core systems are as follows:

1. By designing a tunable antenna with an integral constant coupling to a coaxial transmission line it is possible to avoid entirely the use of any open connecting or lead wires carrying R.F. voltages or R.F. current thus avoiding power loss in transmission and unwanted noise pick up in reception.
2. By means of the motorized control of the tuning of the antenna, the antenna can be located advantageously as far as transmission efficiency is concerned, and practically without regard to the length or position of the wires and transmission cable.
3. The extended connector 49 from the motor to the tuning element makes it possible to locate the tuning coil at the most efficient position in the antenna to accomplish maximum radiation efficiency (center-loading), and at the same time permits keeping the electric motor and associated wiring removed from the active radiating portion of the antenna where its presence could introduce losses and interference.
4. By a careful choice of the ferrous material and the inductor rings of the tuning core it is possible to provide an antenna which has relatively high "Q" or high radiation efficiency over the entire tuning.
5. By carefully designing and maintaining a correct proportion of the amount of inductance introduced by the ferrous core and the amount of inductance cancellation provided by the inductor rings, it is possible in this antenna to present a constant load impedance, for example, 32 ohms, over the entire tuning range.
6. By careful designing and dimensioning of the inductor rings, it is possible to attain maximum tuning effect with a minimum of electrical loss, which in all other cases results from the use of inductor rings. These rings are insulated one from the other, and in cross section present a minimum of capacitance from one ring to the other, thus minimizing the R.F. power loss that would otherwise occur.
7. The dividing of the ferrous section of the core into a plurality of sections resiliently held together provides for flexibility and avoids mechanical damage from impact or strain.
8. The meter of the control unit when in the "tune" position indicates the relative linear mechanical position of the tuning core in the coil, and the scale of the meter is graduated directly in frequency.
9. Because of the coaxial transmission cable and coupling device which is located in the body of the antenna, the main base of the antenna is at ground potential and requires no insulation when mounted on the frame of a vehicle or craft.
10. By means of special circuitry which introduces a voltage drop in the motor circuit at the start of any adjustment, the speed of the motor is relatively slow for the first second of duration, speeding up thereafter. This makes possible delicate adjustment of the position of the tuning element.

11. The electrical design of the antenna provides continuous tuning adjustment over the entire tuning range thereof without the use of electrical relays, tap switches or sliding contacts on the antenna coil, and other devices that normally introduce mechanical wear and faulty electrical contact.

12. The design of the entire antenna unit is such that one can be made weighing no more than five pounds and suitable for small aircraft and helicopters.

13. Since this antenna system eliminates the necessity for separately adjusting the impedance matching ratio with each change of frequency, and the tuning adjustment has been reduced to a simple linear mechanical movement, the arrangement is ideally adaptable to complete automatic operation.

In approaching the problem of the design of a continuously tunable mobile antenna the designer has always been faced with the requirement to simultaneously control two separate variables, namely,

1. Tuning the antenna to resonance with the radio transmitter frequency.
2. Varying the ratio of the impedance matching device to comply with varying base resistance of the antenna with each change of frequency.

These two adjustments are critical to the overall efficiency of the antenna system and must be synchronized.

In this invention the second adjustment has been entirely eliminated. On experimenting with the loading coil of the antenna, it was noted that as the inductance of the coil was varied by use of inductor rings the "Q" was also affected. The more rings that were inserted into the coil the lower the inductance and also the lower the "Q". These phenomena have been used herein for a new purpose, that is, to maintain a constant base resistance of the antenna over its frequency range in addition to tuning the antenna.

Ferrous slugs have been incorporated to increase the tuning range and also affect the above mentioned "new purpose". In order to do this the "Q" of the center loading coil has to keep rising steadily as the ferrous slugs are inserted. This extended effect is accomplished by using high "Q" low permeability iron dust core slugs in conjunction with the inductor rings so that the resulting "Q" rises steadily from the high frequency to low frequency end of the tuning range. The shape (length, thickness, spacing) of the rings, plus correct choice of available tuning slug material results in a coil with the properties which most closely resemble the ideal requirement.

It is believed that this is the first time the above method has been used to achieve a near constant base resistance over a large tuning range.

The following chart illustrates the theoretical development of center loaded whip antenna for constant base resistance.

	2 mHz.	8 mHz.
Electrical values for resonance.	20 pf. 380 uh	20 pf. 23.8 uh
Average whip...	Q=50..... XL=4,850Ω..... R=87Ω..... RR=1.5Ω..... BR=88.5Ω.....	Q=50..... XL=1,212Ω..... R=24.3Ω..... RR=3.5Ω..... BR=27.75Ω.....
Ideal whip.....	Q=100..... XL=4,850Ω..... R=48.5Ω..... RR=1.5Ω..... BR=50Ω.....	Q=25..... XL=1,212Ω..... R=48.5Ω..... RR=3.5Ω..... BR=52Ω.....

NOTES:

Q=XL/R; XL=Q/R; R=XL/Q

where:

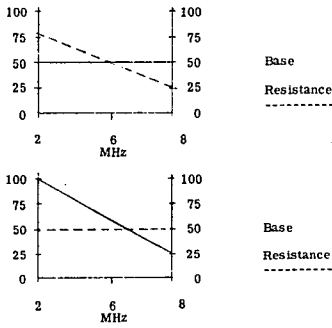
Q=Quality factor of coil.

XL=Inductive reactance of coil.

R=Resistance of the coil (R.F.).

BR=Base resistance.

RR= Radiation resistance.



What is claimed is:

1. An adjustable center-loaded whip antenna arrangement comprising a hollow antenna; a loading coil fixedly mounted in the antenna; and a tuning core mounted for movement through and out of the coil, said core comprising means, comprising a high permeability ferrous section and an inductor ring section, for providing a decrease in the Q of the loading coil with an increase in the tuning frequency of the coil such that a substantially constant radio frequency antenna base resistance is provided over a wide frequency range; the inboardmost end of said ferrous section lying directly adjacent to the inboardmost end of said inductor ring section and the spacing between the outer diameter of the inductor ring section and the inner diameter of the loading coil being a minimum consistent with the necessary insulation required between the core and coil.

2. An antenna arrangement as claimed in claim 1 in which the inductor ring section of the core is made up of a plurality of coaxial inductor rings spaced from each other sufficiently to prevent a short circuit therebetween.

3. An antenna arrangement as claimed in claim 1 in which the ferrous section of the core is made up of a plurality of ferrous slugs resiliently held together as a flexible unit.

4. An antenna arrangement as claimed in claim 1, in which the ferrous section and the ring section of the core are both of such length that each may be in the coil alone.

5. An antenna arrangement as claimed in claim 1 in which the ferrous section and the ring section of the core are each substantially the same length as the coil.

6. An antenna arrangement as claimed in claim 1 in which the inductor ring section of the core is made up of a plurality of coaxial inductor rings spaced from each other sufficiently to prevent a short circuit therebetween; and said rings are not substantially longer than one diameter thereof.

7. An adjustable center-loaded antenna arrangement as claimed in claim 1 in which the inductor ring section of the core is made up of a plurality of coaxial inductor rings spaced from each other sufficiently to prevent a short circuit therebetween, and the ferrous section is made up of a plurality of ferrous slugs, said inductor rings and said ferrous slugs being resiliently held together.

8. An adjustable center-loaded antenna arrangement as claimed in claim 1 further comprising a coaxial R.F. transmission line for connecting an end of the coil to a radio frequency ground through an impedance matching device for coupling said coil to a radio transmitter or receiver, said impedance matching device comprising a capacitor connected at one side thereof to the center conductor of the coaxial line and to a conductor extending to the base of the coil, and at the other side thereof to ground.

9. An adjustable center-loaded antenna arrangement as claimed in claim 8 in which said ground comprises a grounded base portion of the antenna, said other side of the capacitor being connected to the outer shielding of said coaxial line.

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