

Feb. 27, 1951

E. O. WILLOUGHBY
WIDE FREQUENCY BAND ANTENNA

2,543,085

Filed April 13, 1945

2 Sheets-Sheet 1

FIG. 1.

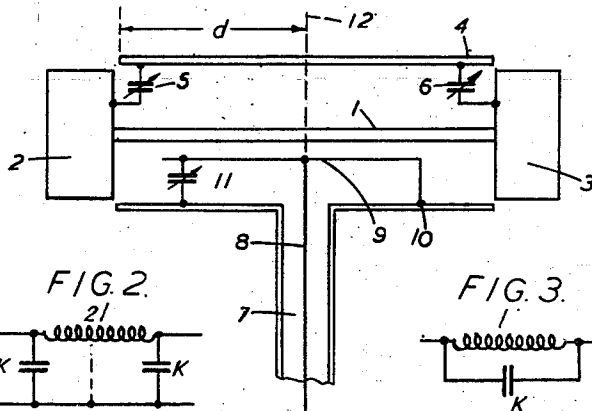


FIG. 2.

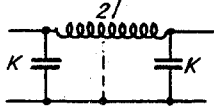


FIG. 3.

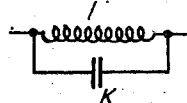


FIG. 4.

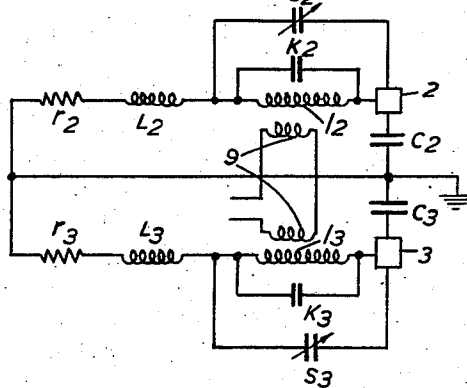


FIG. 7.

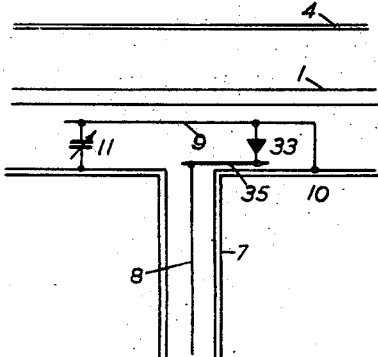
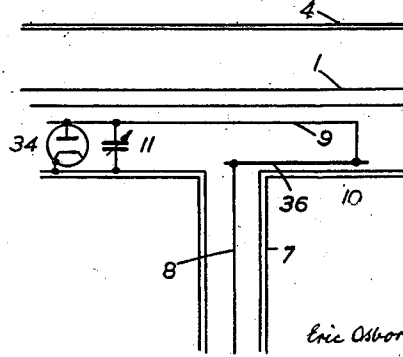


FIG. 8.



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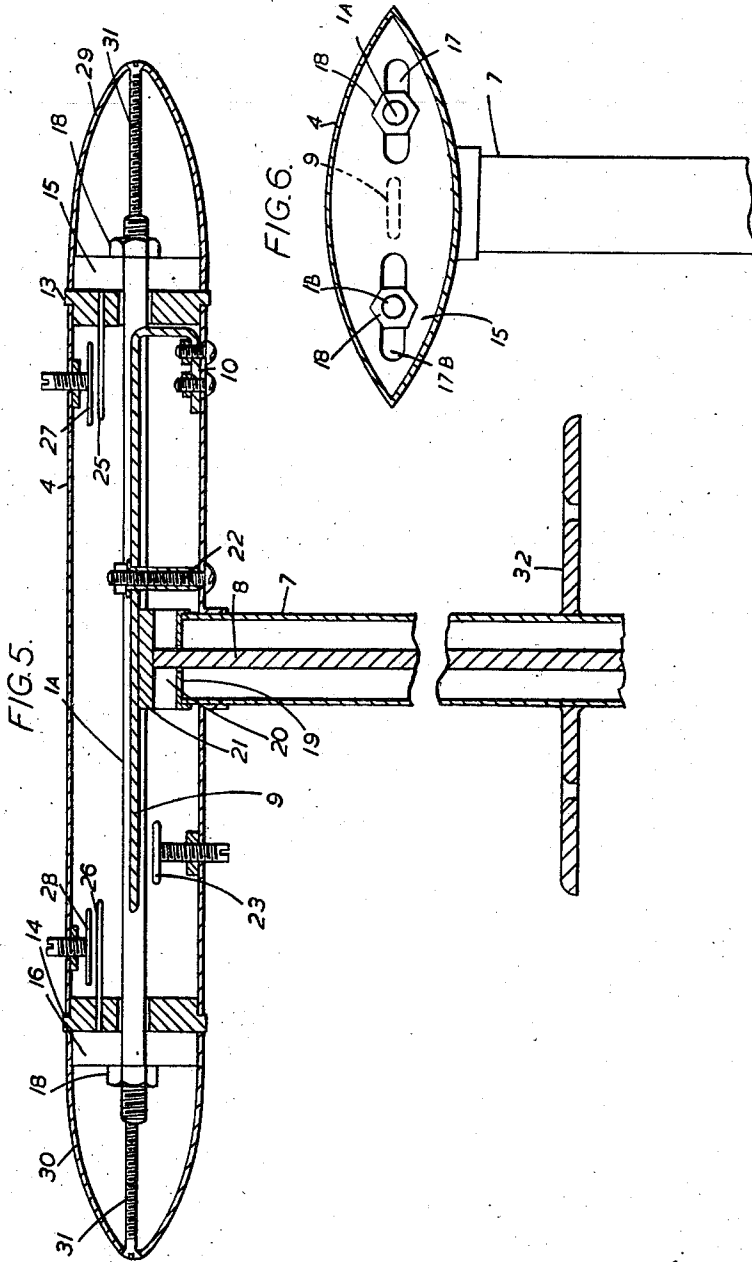
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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

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WIDE FREQUENCY BAND ANTENNA

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6 Claims. (Cl. 250-33)

1

The present invention relates to radio antennas, and concerns particularly antennas of small size adapted for stream lining for use on aeroplanes.

It is frequently found that antennas used on aeroplanes are liable to be broken off by the air resistance when driving at very high speed. It is therefore most desirable that the antenna should be as small as possible so that the minimum air resistance be offered.

The present specification describes a new type of dipole antenna which can be made very short compared with the wave-length, (for example about one fifth).

According to the invention, there is provided a radio antenna comprising a hollow metallic body enclosing two electromagnetically coupled resonating systems both tuned to the operating frequency, and a transmission line feeder for conveying currents to or from the antenna coupled to one of the said systems.

According to the invention also there is provided a radio antenna comprising a hollow resonator, a resonating circuit inside the said resonator and coupled electromagnetically thereto, and a transmission line coupled to the said circuit, the said resonator and circuit being each tuned to the operating frequency.

The invention also provides a radio antenna comprising a hollow coaxial resonator, a resonating input transmission line inside the said resonator and coupled thereto, and a transmission line feeder for conveying currents to or from the antenna coupled to the said input line, the said input line and resonator being tuned to the operating frequency.

The invention will be described with reference to the accompanying drawings, in which:

Fig. 1 shows diagrammatically the features of an antenna according to the invention;

Figs. 2, 3 and 4 show equivalent circuits employed in explaining the action of the antenna;

Figs. 5 and 6 show respectively a longitudinal sectional view, and an end view (with the cap removed), of an antenna constructed according to the invention; and

Figs. 7 and 8 show diagrams corresponding to part of Fig. 1 to show the manner in which a rectifier may be connected inside the antenna.

Fig. 1 shows diagrammatically an antenna according to the invention. It comprises a rod or wire conductor 1 loaded at the ends with relatively large metal masses 2 and 3. Surrounding the conductor 1 is a hollow cylindrical body 4 forming therewith a hollow resonator consisting of an inner coaxial transmission line open at

2

both ends, which ends are terminated by the capacities between the body 4 and the masses 2 and 3. These terminating capacities may be supplemented by adjustable tuning capacities 5 and 6.

Currents are led to or from the antenna by a coaxial transmission line feeder 7 entering the body 4 at the median plane 12, and the central conductor 8 is connected to a point on a conductor 9 placed inside the body 4 parallel to the rod 1. The conductor 9 is connected at 10 to the wall of the body 4 (either directly or through an appropriate blocking condenser, not shown) and the other end is terminated by a tuning condenser 11.

The conductor 9 forms with the body 4 a tuned input transmission line whose electromagnetic field is coupled with that of the resonator formed by the conductor 1 and the body 4. The system is equivalent to two coupled resonant circuits both of which should be tuned to the frequency of the waves to be radiated or received. According to the usual practice with coupled tuned circuits, the Q value (ratio of reactance to resistance) of the two circuits should be the same and they should be sufficiently over coupled (that is, the coupling factor should be a little greater than the critical coupling factor) in order to widen the pass band as may be necessary.

The rod 1 with the two masses 2 and 3 forms a dipole antenna, but its potential variations are transferred to the outer surface of the enclosing body 4 which thus acts as the real radiator. The physical length of the rod 1 and body 4 can be small compared with the wave length (for example about one fifth of the wave length). The inner transmission line will have a voltage node at the median plane 12 and a current antinode, and the current at any instant will be nearly the same at all points of the body owing to its short length.

Under these conditions the short inner coaxial transmission line formed by the rod 1 and the body 4 as seen from the open ends is substantially equivalent to the network of lumped reactances shown in Fig. 2. Let $2d$ be the total length of the body 4 and let $\theta = 2\pi d/\lambda$ where λ is the wave-length, then it is easily shown that the reactance of each of the equivalent condensers K is $-jZ_1 \cot \theta$, and the reactance of the inductance 21 is $jZ_1 \sin 2\theta$, in which Z_1 is the characteristic impedance of the inner transmission line. This line being open at both ends, (assuming that the excitation by the conductor 9 is balanced), there will be a voltage node at the centre on the median plane 12, and so as seen

from either end, the network of Fig. 2 is in effect short circuited in the centre as indicated by the dotted line. The inner transmission line therefore presents an impedance at either end which may be represented by the network of Fig. 3.

The outer surface of the body 4 can be regarded as forming with ground an outer transmission line open at both ends, there being a voltage node at the median plane 12. If Z_2 is the characteristic impedance of this outer transmission line, then the reactance presented by this line at each open end will be $jZ_2 \tan \theta$.

It is now possible to construct an approximate equivalent circuit for the antenna of Fig. 1. This is shown in Fig. 4. The small squares 2 and 3 represent the end masses 2 and 3 of Fig. 1. These are shown connected to earth by approximately equal capacities C_2 and C_3 . The mass 2 is also connected to ground through the two open end impedances of the inner and outer transmission lines, which are in series. These are represented respectively by the network L_2 , K_2 , and by the inductance L_2 in series with a resistance r_2 representing the radiation resistance of half the antenna. Similarly the mass 3 is connected to earth through corresponding impedances L_3 , K_3 , and L_3 , r_3 , where

$$\omega L_2 = \omega L_3 = \frac{1}{2} Z_1 \sin 2\theta$$

$$\omega K_2 = \omega K_3 = 1/Z_1 \cot \theta$$

$$\omega L_2 = \omega L_3 = Z_2 \tan \theta$$

where ω is 2π times the frequency.

The condensers S_2 and S_3 are the tuning condensers 5 and 6 shunted across the open ends of the inner transmission line.

The exciting conductor 9 is represented in Fig. 4 by two series connected windings coupled respectively with L_2 and L_3 . The excitation is such that the potentials of 2 and 3 are equal and opposite, so that the two halves of Fig. 4 are effectively in series. S_2 and S_3 will be adjusted so that the series circuit resonates at the operating frequency. As all the elements of the circuit are known the effective Q value can be determined. For example, if the antenna be supposed to be cut in half on the median plane 12, then a resonance curve relating to the impedance looking into the cut end to the frequency can be determined for half the antenna, from which the Q value can be found.

By suitable choice of the impedance of the transmission line 7 (Fig. 1) and the manner in which the conductor 8 is connected to the conductor 9, the Q of the input circuit may be made to have the same value.

In order that the antenna may be efficient it is necessary that the masses 2 and 3 should be made relatively large, so that the reactances of C_2 and C_3 are reasonably small, otherwise the series circuit of Fig. 4 will have such sharp tuning that only a small band width can be handled by the antenna.

Figs. 5 and 6 show one form in which an antenna according to Fig. 1 may be made up. The body 4 has the flattened segmental section indicated in Fig. 6. The conductor 1 of Fig. 1 is represented by two parallel rods 1A and 1B, the ends of which are seen in Fig. 6. In Fig. 5 only the rod 1A is visible.

The ends of the body 4 are closed by insulating plates 13 and 14. Outside these plates are fixed similarly shaped metal plates 15 and 16. The plates 13, 14, 15 and 16 have clearance slots 17A and 17B for the rods 1A and 1B, and the parts

are clamped together by means of the nuts 18 which screw on the ends of the rods at both ends. The slots permit the spacing of the rods to be adjusted.

The conductor 9 of the input line comprises a flat strip arranged between the rods 1A and 1B. The strip 9 is bent round at one end and clamped by screws to the body 4 at 10. The conductor 8 of the transmission line 7 passes through an insulating disc 19 closing the end of the tube and is secured to a metal disc 20 which rests on the disc 19. Another insulating disc 21 covers the metal disc 20, and the strip conductor 9 rests on the top of the disc 21, being held down by the screw 22 provided with an insulating sleeve and washer, as shown, to prevent the strip 9 from being short circuited.

A small metal disc 23 carried on a screwed shank passing through the wall 4 is arranged below the strip 9 and forms therewith an adjustable condenser corresponding to 11 of Fig. 1.

The plates 15 and 16 are provided with metal tongues 25 and 26 soldered or otherwise electrically secured thereto. These tongues pass through corresponding slots in the plates 13 and 14. Discs 27 and 28 with screwed shanks similar to 23 pass through the walls of the body 4 and form with the tongues 25 and 26 adjustable condensers corresponding to 6 and 5 of Fig. 1. Two streamlined end caps 29 and 30 are slipped over the plates 15 and 16 and are fixed by screws 31 into the ends of the rods 1A and 1B. The end caps together with the metal plates form the large leading masses 2 and 3 of Fig. 1.

The transmission line 7 is provided with a foot or flange 32 by which the antenna may be fixed to the underside of a wing of an aeroplane, for example. The transmission line 7 should be about a quarter wavelength long.

The use of two parallel rods to form the conductor 1 enables the characteristic impedance of the inner transmission line to be given a suitable value, and the coupling factor between the inner transmission line and the input line may be adjusted by adjusting the spacing of the rods in the slots 17A and 17B. It is, of course, not essential to use two rods. One of them could be omitted, or more than two could be used.

The section of the body 4 of the antenna is only approximately correctly stream-lined. The sharp forward edge sets up some eddies which assist in the prevention of ice formation. The end caps may be suitably stream-lined for end-on movements. The co-axial transmission line 7 may be stream-lined by means of a suitably shaped vane (not shown) which can turn in the wind.

It will be noted that the conductor 8 is not connected directly to the conductor 9, but is coupled thereto through a capacity potentiometer. The disc 20 forms condensers respectively with the body 4 and with the conductor 9, which condensers are in series, and the conductor 8 is connected to the common point of the two condensers.

By suitable choice of the capacities of these condensers, the impedance of the transmission line 7 may be made to load the input line so as to produce the desired value of Q. If a direct connection were made between the conductors 8 and 9, this connection would probably need to be inconveniently near one end of conductor 9.

When the antenna is used as a receiver, a suitable rectifier may very conveniently be housed inside the body 4. If a low impedance rectifier

(such as a copper oxide or selenium rectifier) is used, it may be connected as shown diagrammatically in Fig. 7. A plate 35 insulated from the body 4 forms a by-pass condenser. The rectifier 33 is connected between the conductor 9 and the plate 35 near the end 10 of the conductor 9. The conductor 8 is in this case connected to the plate 35 and not to the conductor 9, and carries the rectified current, the radio frequency current being by-passed. When a high impedance rectifier, such as a diode, is used, it may be connected as shown in Fig. 8. The plate 36 is insulated from the body 4 to form a by-pass condenser, and the conductor 9 is connected to this plate at 10. The conductor 8 is also connected to the plate 36. The diode 34 is connected at the other end of the conductor 9 near the condenser 11. Again the rectified current flows to the conductor 8, and the radio frequency current is by-passed at 10.

What is claimed is:

1. A radio antenna of the dipole type with means for rendering said antenna short compared to the operating frequency comprising a coaxial line type section open at both ends, a capacitive load coupled across each end of said coaxial section, said coaxial section being dimensioned to resonate with said capacitive loads at the operating frequency, a circuit resonant at the operating frequency and coupled to said coaxial section at the center thereof, and a translating device coupled to said resonant circuit.

2. An antenna according to claim 1 in which said resonant circuit comprises a conductor mounted parallel to and spaced from the inner conductor of said coaxial section and means connecting said conductor of said resonant circuit to the outer conductor or said coaxial section.

3. An antenna according to claim 1 in which said capacitive loads comprise metallic masses substantially closing the respective ends of said coaxial section and providing relatively large capacities to earth.

4. An antenna according to claim 1 in which said resonant circuit comprises a conductor inside said coaxial section and parallel to the axis thereof, said conductor being connected at one of its ends to the outer conductor of said coaxial section and a tuning condenser connecting said conductor of said resonant circuit at the other of its ends to the outer conductor of said coaxial section.

5. An antenna according to claim 1 further comprising a capacity potentiometer connecting said translating device to said resonant circuit.

6. A radio antenna according to claim 1 further comprising a rectifier connected across said resonant circuit.

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