

March 18, 1952

R. W. P. KING

2,589,818

ANTENNA

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2 SHEETS—SHEET 1

Fig. 1.

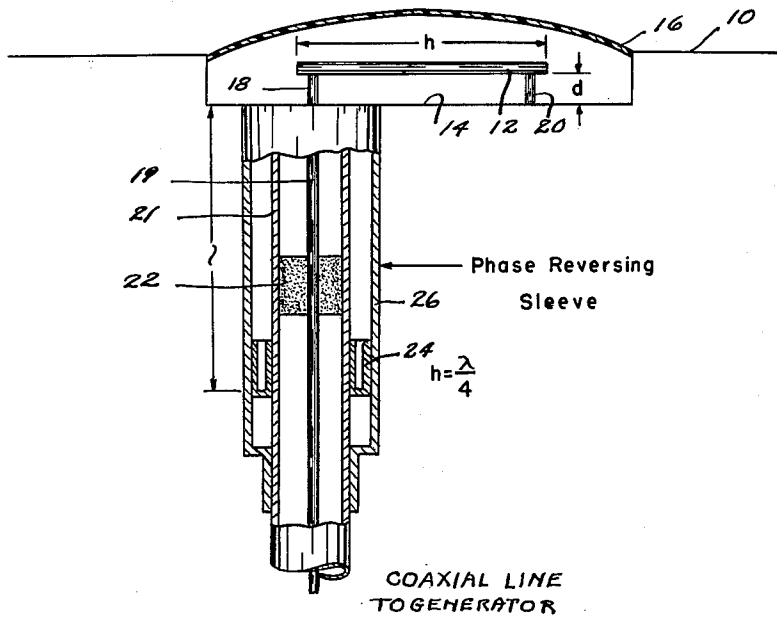
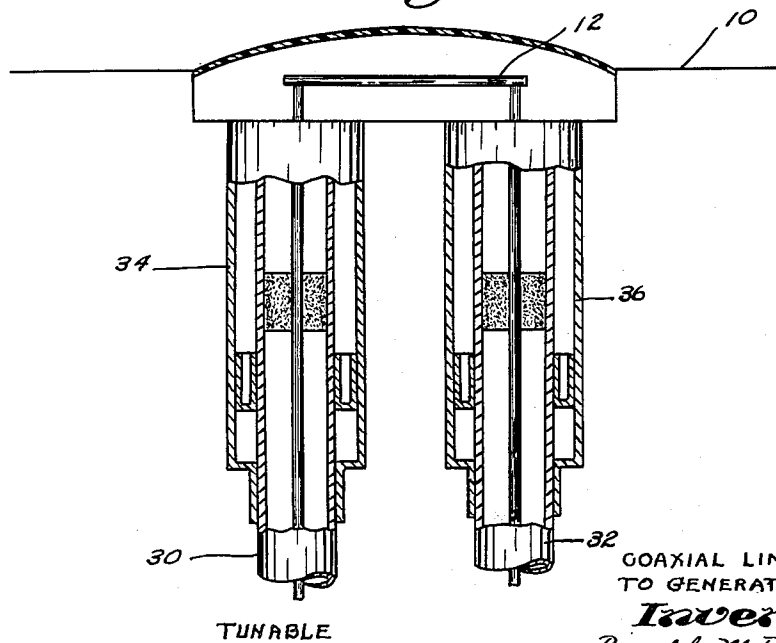


Fig. 2.



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2 SHEETS—SHEET 2

Fig. 3.

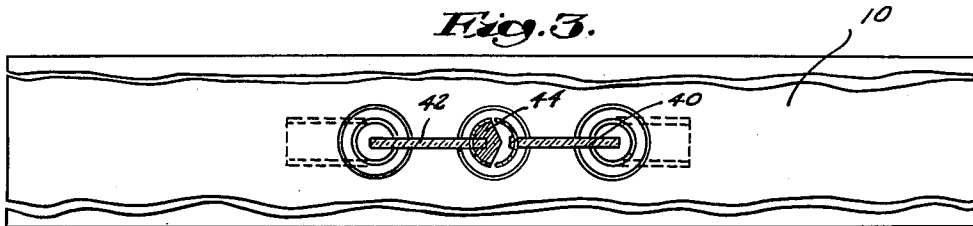


Fig. 4.

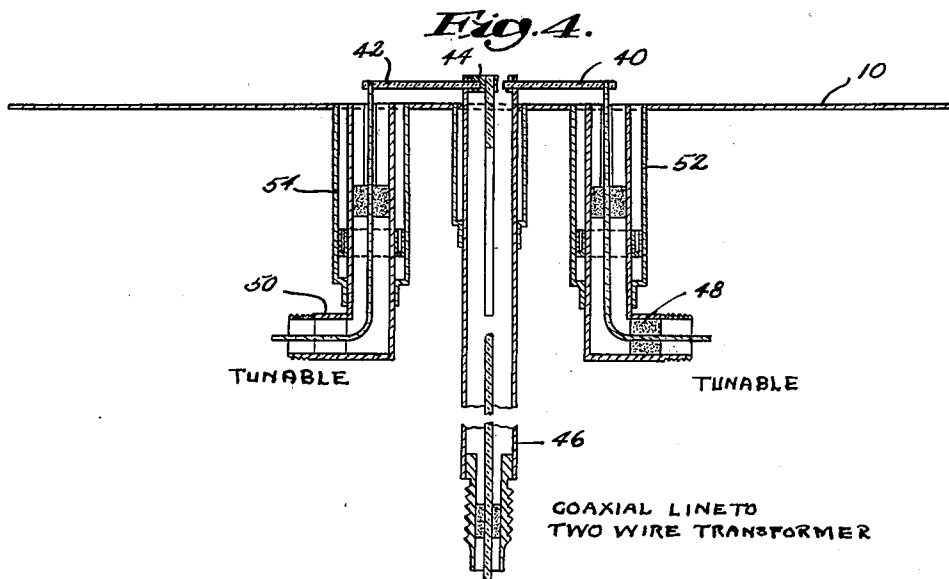


Fig. 6.

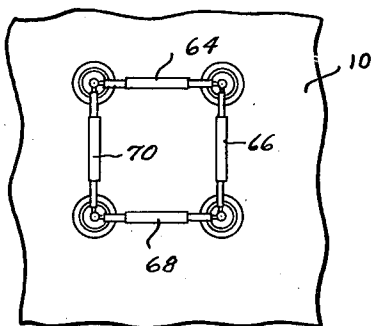
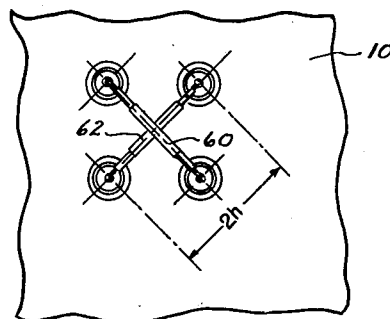


Fig. 5.



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UNITED STATES PATENT OFFICE

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This invention relates to antennas. More particularly the invention deals with antennas of the type which are employed in the very high frequency bands and which are suitable for use with metal surfaced, high speed aircraft.

As is well known, if electric currents are passed along a conductor, some electrical energy passes out into space. When the conductor is extended so that its length is an appreciable part of a wave length, then the amount of energy radiated as compared with that dissipated as heat may be relatively large and the radiation is more efficient. At low frequencies the wave length is very large while at very high frequencies the wave length may be quite small as represented by the formula

$$\lambda = \frac{3 \times 10^8 \text{ m./sec.}}{f}$$

where f denotes frequency value and λ indicates wave length. At very high frequencies antennas a few inches in length representing a quarter wave or half wave are commonly employed with a half wave antenna usually being referred to as a "dipole."

At speeds of 300 M. P. H. and higher, a projecting member such as an antenna materially affects the speed of the plane and is in addition difficult to maintain in position. As a consequence, means must be provided to recess the antenna in the metal hull of the aircraft. Here a new problem presents itself since the metal surface of the plane in close proximity to the antenna affects its radiation efficiency.

It is well known for example that if a conducting member such as a rod is brought close to a center driven

$$\frac{\lambda}{2}$$

dipole, radiation will be greatly reduced due to an oppositely directed current induced in the rod by the dipole. However, if the ends of the antenna are connected directly to the rod this is no longer the case. The currents in the dipole and rod are then almost exactly in phase. The resulting device as is known has a large radiation resistance and is called a "folded dipole." The reason for the reversal of current is that the induced current that would be set up in the rod is exceeded by the in phase current induced directly in the rod by the charge concentrations at its ends.

Although this solution to the difficulty noted is suitable for a rod member, it does not afford a means of preventing reduction in radiation in

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the case of a relatively large flat sheet such as is constituted by the metal surface of an airplane in which the antenna is recessed. The radiation from such a section is extremely small, only out of phase current being present at the surface of the plane.

An object of the invention therefore is to provide an improved antenna for use in airplanes with a view to overcoming the reduction in radiation resulting from proximity of the antenna to a relatively large flat surface of the plane. Other objects will appear from the following description of the invention.

In this connection, I have discovered that a relatively large conducting surface need not necessarily reduce greatly the radiation resistance of a dipole if means is used to excite currents in the conducting surface, which are in phase with the dipole current, rather than to excite just the out of phase image currents. I have further found that I may combine with a dipole member additional conducting means so arranged that it functions to reverse the phase of currents induced in the flat surface. An important feature of the invention therefore is the combination with a dipole recessed in a relatively large metal surface of a phase reversing conductor element which provides for the development and maintenance of more efficient radiation.

The drawings illustrate preferred embodiments of the invention in which

Figure 1 is a cross sectional view diagrammatically illustrating the antenna of the invention recessed in an airplane surface.

Figure 2 is a cross sectional view diagrammatically illustrating a modification of the invention;

Figure 3 is a fragmentary plan view illustrating still another modification;

Figure 4 is a cross sectional view of an antenna structure similar to that shown in Fig. 3; and

Figures 5 and 6 indicate alternate arrangements of antenna structure such as that shown in Fig. 1.

Considering in greater detail the structures shown in the drawings, I have indicated diagrammatically at several points airplane surfaces which are recessed to receive different types of antenna members of the invention. These antennas are all in general referred to as "Bar Antennas." Each of them is further classified by reference to their structural details or their mode of activation. Thus in Fig. 1 is illustrated a "half bar" antenna; in Fig. 2 is illustrated an "end-driven bar antenna"; in Figs. 3 and 4 is illustrated

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a "center-driven bar antenna"; in Fig. 5 is illustrated a "crossed bar antenna"; and in Fig. 6 is illustrated a "parallel bar antenna."

The half bar antenna indicated in Fig. 1 will now be described and this explanation, to a large extent, applies to the other antennas shown. Numeral 10 denotes the airplane surface in which is formed a recessed area 14. A metal bar 12 is located in parallel spaced relation above the area 14. The bar member is of a length h which may for example be

$$\frac{\lambda}{4}$$

A protecting cap 16 of a dielectric plastic material may be provided to cover the recessed area and the rod member 12.

At either end of the bar member are secured conductors 18 and 20. The conductor 20 is connected to the surface 14. The conductor 18 extends downwardly through the surface 14 and is slidably received in a cylindrical casing 19. The conductor 18 and the casing 19 together constitute a central conductor element of a coaxial line as illustrated at the left-hand side of Fig. 1. Surrounding the conductor 18 and casing 19 is a metal tubing 21 which forms the outside conductor element of the coaxial line. The ratio of the diameter of the inner and outer conductors may be so chosen as to provide for suitable attenuation characteristics in accordance with the well known properties of coaxial lines.

The tubing 21 is maintained in spaced relation around the central conductor element by means of an insulating disc 22. The coaxial line is connected to a generator in the usual manner by means of which electrical oscillations are supplied. By adjusting the position of the conductors 18 relative to the casing 19, the spacing d of the rod 12 from the recessed surface may be varied.

In accordance with the invention, I further combine with the coaxial line a metal collar 24 having a U-shaped cross section. The collar is secured around the tubing 21 in the manner shown. Supported on this collar is another metal tubing or sleeve member 26 which with the collar and the outer surface of 21 constitutes a phase-reversing sleeve assembly. The tubing 26 spaced away from the tubing 21 and at its lower end is of reduced diameter to allow for sliding contact with the coaxial line and to provide for the phase-reversing sleeve assembly being conductively closed at its bottom. The distance between the conductively closed portion of the collar 24 and the airplane surface is preferably

$$\frac{\lambda}{4}$$

The position of the outer sleeve may be varied relative to the coaxial line to locate it in a proper or tuned position at which maximum beneficial effects are secured.

The purpose of the phase-reversing sleeve 26 is to increase the efficiency of radiation by spreading the current on the surface of the plane. Without the sleeve it is pointed out that the surface current is just the image current of the bar 12. This current value falls off very quickly as one moves away from beneath the bar. The efficiency of radiation would also be very small since this current is opposite in direction to the current in the bar and hence tends to cancel its fields so that much larger currents would be required with correspondingly greater heat loss.

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It should be observed that the conductor 18 and the inner surface of the immediately surrounding cylindrical tube 21 act as a

$$\frac{\lambda}{4}$$

open end section of coaxial line as far as current and charge distribution are concerned, i. e. a voltage maximum occurs at its top.

The sleeve 26 arranged in the manner noted provides a coaxial cavity whose impedance to a potential difference across its open end is very large. This permits large concentrations of charge of opposite sign at the top of the two tubings. A maximum of current occurs at the bottom of this cavity. The large concentrations of charge at the upper rim of the outer tubing function to excite current on the plane surface. The currents thus induced are in phase with the currents in the bar and therefore opposite to normal image currents. These in-phase currents in the plane surface thus serve to keep the radiation efficiency relatively high.

It will be seen that with a given bar current, one effect of the sleeve is to reduce or reverse the image currents. The practical effect of this on the behavior of the antenna is to increase both its radiation resistance and its efficiency.

It will also be apparent that an appreciable radiated field can be maintained by the currents in the sleeve and the plane surface. The currents in the phase-reversing sleeve section build up to quite large values, as in a resonant circuit, and these currents together with the surface currents on the sheet produce a significant radiation field.

The radiation field can in most cases be considered as due to the bar current and its image plus the currents in the sleeves and their images. The relative importance of the phase-reversing sleeves and the bar is determined by the ratio of the radius γ of the sleeve 26 to the height d of the bar 12 as indicated in Fig. 1. For the extreme condition of d being very much less than γ the phase-reversing sleeve and the image contribute most of the radiation; the bar and its image in this case merely acts as a two-wire line over which energy is fed to these sleeves. As this relation changes, the bar plays a greater part in providing radiation. It should also be noted that the phase-reversing sleeve if of sizeable diameter is an important factor in determining the distribution of surface current as well as the radiation field.

The end-driven bar antenna structure shown in Fig. 2 is similar to the antenna already described with the difference that two coaxial lines 30 and 32 and two phase-reversing sleeve assemblies 34 and 36 respectively are employed. One coaxial line is connected to a generator and the other as is noted on the drawings is tunable as with a piston. The sleeve assemblies 34 and 36 are so adjusted as to provide maximum efficiency.

In Figs. 3 and 4 there is indicated one suitable center-driven bar antenna arrangement by which phase-reversing sleeves may be employed to advantage. In this arrangement rod sections 40 and 42 are connected to a two-conductor line 44. The coaxial cable 46 from the transmitter is connected to the two-conductor line 44 by a balanced to unbalanced line transformer section. Two coaxial lines 48 and 50 are connected to the sections 40 and 42 and are provided with phase-reversing sleeves 52 and 54. The two side fittings are each connected to an adjustable length of line; or they may be connected together by an adjustable length of coaxial line. The adjust-

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ment in either case is for the optimum location of the current maximums.

In Fig. 5 I have shown crossed bars 60 and 62 to produce a circularly polarized field. They are likewise equipped with phase-reversing sleeve assemblies. Similarly, in Fig. 6 there is illustrated a parallel bar arrangement with bars 64, 66, 68, and 70, each being provided with phase-reversing sleeve assemblies. By varying the arrangement of the bar antenna in the manner indicated in Figs. 3, 4, 5 and 6, various other changes in the effects produced and the operating characteristics may be obtained.

From the foregoing it will be seen that I have provided an efficient, positive and simple antenna structure which is particularly suited to use with airplanes at high speeds and the difficulties arising out of recessed mounting of an antenna in a metal surface are almost entirely eliminated.

It is intended that the invention may be modified in various respects in accordance within the limits defined by the claims.

I claim:

1. An antenna for metal aircraft comprising, an antenna conductor recessed below the air stream surface of the plane, and substantially parallel thereto, a dielectric cover closing the recess, a metal image plate beneath the antenna conductor and substantially parallel thereto, a coaxial transmission line having its central conductor connected to one end of the antenna and its outer conductor terminating in an open end, and means for impressing reverse phase currents on said image plate, said reverse phase means including a tubular conductor surrounding said coaxial line and connected at one end to said image plate and to the coaxial line at the other end.

2. An antenna for metal aircraft comprising, an antenna conductor recessed below the air stream surface of the plane and substantially parallel thereto, a dielectric cover closing the recess, a metal image plate beneath the antenna conductor and substantially parallel thereto, a coaxial transmission line having its central conductor connected to one end of the antenna and its outer conductor terminating in an open end, and means for impressing reverse phase currents on said image plate, said reversing means including a spaced tubular conductor surrounding the coaxial line one end being connected to the outer surface of the coaxial line at a point substantially a quarter wave length from said open end, the other end being connected to said metal image plate, the structure including the outer line conductor, the spaced tubular conductor and the connection therebetween constituting a phase reversing cavity resonator.

3. An antenna for metal aircraft comprising, an antenna conductor recessed below the air stream surface of the plane and substantially parallel thereto, a dielectric cover closing the recess, a metal image plate beneath the antenna conductor and substantially parallel thereto, a coaxial transmission line having its central conductor connected to one end of the antenna and its outer conductor terminating in an open end, and a connection from the other end of the antenna to the image plate, and means for impressing reverse phase currents on the image plate, said phase reversing means including a spaced tubular conductor surrounding the outer line conductor and forming therewith a tunable cavity resonator, one end of the tubular conductor being connected to the outer line conductor at a

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point substantially a quarter wave length from said open end, the other end being connected to the aforesaid image plate.

4. An antenna for a metal aircraft comprising an antenna conductor recessed below the air stream surface of the plane and substantially parallel thereto, a dielectric cover closing the recess and means for increasing the radiation efficiency of the antenna, said means including a metal image plate beneath the antenna conductor and means for exciting the image plate with reverse phase currents, means for direct phase excitation of the antenna including a coaxial transmission line having its inner conductor connected to the antenna and its outer conductor terminating in an open end substantially in the plane of said image plate, said reverse phase exciting means including a quarter wave cavity resonator open toward the antenna and connected between the outer line conductor and the image plate, said cavity resonator being formed by a spaced tubular conductor surrounding the outer line conductor, one end being connected thereto at a point substantially a quarter wave length from said open end and the other end being connected to said image plate.

5. An antenna for an airplane recessed beneath the air stream surface comprising, a coaxial transmission line having its central conductor connected to the antenna and its outer conductor terminating in an open end, and means for increasing the antenna radiation efficiency, said radiation efficiency means including a metal image plate spaced apart and parallel to the antenna conductor and means for impressing reverse phase currents on said image plate, said reverse phase means including a spaced tubular conductor surrounding the coaxial line and connected thereto at a point substantially a quarter wave length from said open end and forming therewith a tunable cavity resonator, and a connection from the other end of said tubular conductor to said image plate.

6. An antenna for aircraft recessed beneath the air stream surface comprising, a metal image plate beneath the antenna, a coaxial transmission line for supplying antenna energy having a slidable connection from the central conductor to one end of the antenna the outer line conductor terminating in an open end, a second coaxial line having a central slidable connection to the other end of the antenna the outer line conductor terminating in an open end in line with first open end and an adjustable tuning slug for shorting the central conductor to the outer conductor, and means for impressing reverse phase currents on the image plate for increasing the antenna efficiency, said reverse phase means including a tubular conductor at the end of each line coaxial with and external thereto, a slidable annular tuning ring for each line connecting each outer line conductor to its corresponding tubular conductor at points substantially a quarter wave length from said open ends respectively and forming therewith a tunable cavity in each space between the respective tubular conductors and coaxial lines, and a connection from the ends of the tubular conductors to the aforesaid image surface.

7. An antenna for aircraft comprising, a center-fed antenna recessed beneath the air stream surface, a metal image plate beneath the antenna, a coaxial transmission line connected to the center of the antenna, and means for impressing reverse phase currents on the image

plate for increasing the antenna efficiency, said reverse phase means including two tunable coaxial lines each having the central conductor connected to one end of the antenna each outer conductor terminating in an open end at the level of the image plate and a tubular conductor at the end of each line concentric with and external thereto, a slidable annular tuning ring for each line connecting the outer line conductor to its corresponding tubular conductor at a point substantially a quarter wave length from said open ends respectively and forming therewith a tunable cavity in each space between the respective tubular conductors and coaxial lines, and a connection from the ends of the aforesaid tubular conductors to the image plate.

8. An antenna system for producing a circularly polarized field for aircraft recessed beneath the air stream surface comprising a pair of antennas with their electric axes positioned at right angles and in planes parallel to the surface of the aircraft, a metal image surface beneath the antennas, a coaxial transmission line for each antenna for supplying power having its central conductor connected to one end of one antenna and its outer conductor terminating in an open end, a second transmission for each antenna having its central conductor connected to the other end of an antenna and its outer conductor terminating in an open end, means for tuning each second transmission line, and means for impressing reverse phase currents on the image plate for increasing the antenna efficiency said reverse phase means including a tubular conductor at the end of each aforesaid coaxial line coaxial with and external thereto and having a slidable annular tuning ring connecting the outer line conductor to its corresponding tubular conductor at a point substantially a quarter wave length from said open end and forming therewith a tunable cavity for each line in the space between the line conductor and its external tubular conductor, and a connection from the ends of each tubular conductor to the image plate.

9. An antenna system for producing a circularly polarized field for aircraft recessed beneath the air stream surface comprising four antennas arranged in a square with their ends joined together, a metal image surface beneath the antennas, two coaxial transmission lines for supplying power each having its central conductor connected to one of said antenna junctions at opposite vertices of said square and its outer conductor terminating in an open end, two tunable coax-

ial transmission lines each having its central conductor connected to one of said antenna junctions at the remaining vertices of the square and its outer conductor terminating in an open end, and means for impressing reverse phase currents on the image plate for increasing antenna efficiency, said reverse phase means including a tubular conductor at the end of each aforesaid coaxial line concentric with and external thereto and having a slidable tuning ring connecting the outer line conductor to its corresponding tubular conductor at a point substantially a quarter wave length from said open end and forming therewith a tunable cavity for each line in the space between the line conductor and its external tubular conductor, and a connection from the end of each tubular conductor to the image plate.

10. In an antenna system, an antenna element, a coaxial feed line at right angles thereto having a central conductor connected to one end of said antenna element and an outer conductor terminated in an open end, a metal image plate spaced apart from and parallel to said antenna, a connection from the other end of the antenna to said image plate, and means for supplying currents to the image plate in reverse phase from those normally induced by the antenna, said reverse phase means including a tubular conductor surrounding said line and connected thereto at a point substantially a quarter wave length from said open end and a connection from the other end of said tubular conductor to said image plate.

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