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C. D. PERRINE, JR

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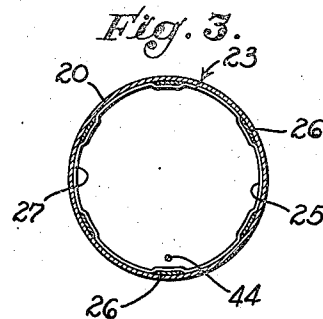
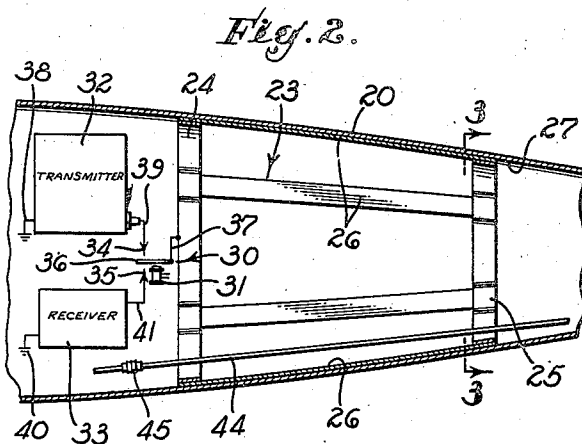
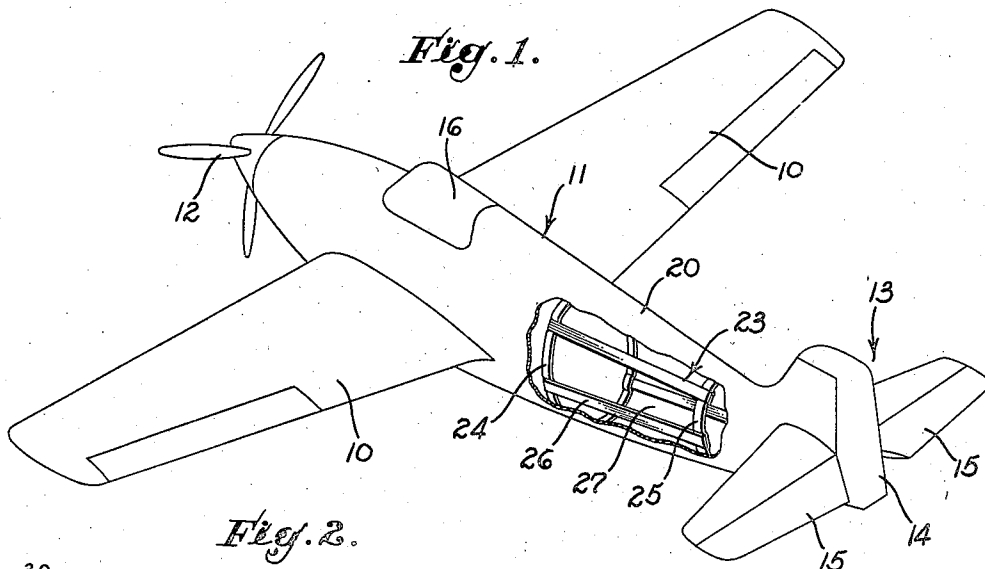


Fig. 4.

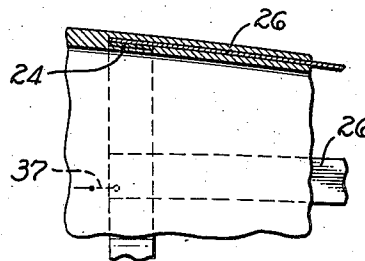
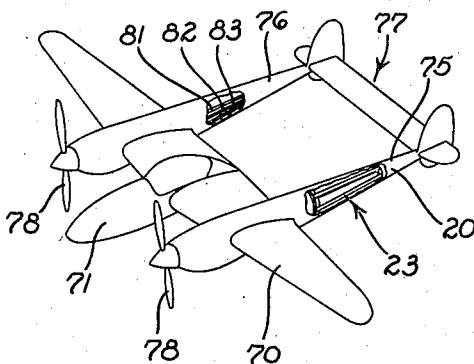


Fig. 5.



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My invention relates to aircraft and, more particularly to a novel aircraft antenna system adapted for radio transmission at high altitudes from airplanes formed wholly or partly of plastics, plywood, or other electrically non-conducting materials.

Conventional single-wire antennas now employed in aircraft for transmission and reception of radio signals are open to many objections. Being positioned in the air stream, they are disadvantageous from an aerodynamic standpoint as they increase the parasitic drag. They are also subject to weathering, accumulation of ice, and to vibration tending toward fatigue failure, as well as being subject to severance through accidents, gun fire in combat, etc., which would render the radio system inoperative.

It is an object of the present invention to provide an antenna system which is out of the air stream so as to avoid parasitic drag, and which is preferably within the confines of the outermost surfaces of the aircraft; to provide an antenna system which is not subject to weathering or icing conditions nor to air-stream-induced vibration; to provide an antenna which may be unitary with a portion of the airplane; and to provide an antenna system which is protected against accidental breakage, which requires no servicing or maintenance, and which is not vulnerable to gun fire. It is a further object of the invention to provide an antenna which is formed of a plurality of sections so connected that breakage or severance of any particular section will not render the antenna ineffective.

A conventional single-wire antenna has, in addition, many electrical disadvantages. It has a frequency-response curve which is relatively sharp and radio transmission at other than a resonant frequency requires the use of tuning expedients to permit transmission or reception of radio signals of different frequency. It is usually connected in an antenna circuit tuned by a variable impedance which absorbs a large amount of the available power, in some instances up to 90% thereof. The power available from the transmitter is usually limited, being conventionally in the neighborhood of 100 watts, and any absorption reduces the power available for radiation from the antenna.

It is an object of the invention to decrease this power loss and increase the radiation from the antenna; to provide an antenna system which is of the broad-tuning type to have a broader frequency response than a single-wire antenna; and to provide an antenna in which the rate of change

of impedance over a given band of frequency is less than when a conventional single-wire-type antenna is employed.

A single-wire antenna system represents a relatively low-capacity system as the "free space" capacity is low. This capacity increases with the equivalent surface area of the antenna configuration, and it is an object of the present invention to provide a relatively high-capacity, low-impedance antenna system for aircraft whereby the voltage required for development of the same amount of power is lessened.

Application of high voltages to an antenna system during high altitude flight gives rise to difficulties as the breakdown voltage of air decreases very substantially with increase in altitude. Thus, for example, a potential of 1000 volts will jump an air gap approximately three times as wide at a 40,000 foot elevation as at sea level. If the same antenna is used for radio reception and transmission, it is necessary to utilize a double-pole switch in the antenna circuit, usually a relay providing a movable contact selectively engaging a pair of side contacts connected respectively to the output of the transmitter and the input of the receiver. If the transmitter is or remains energized during high altitude flight, as is desirable, there is a marked tendency for electrical breakdown of the gap between the side contacts, with consequent injurious delivery of the transmitter output to the input of the receiver. In addition, corona formation is enhanced at high altitude, representing not only a substantial waste of power but also the danger of heating and burning surfaces adjacent the antenna or other portions of the antenna circuit. Corresponding breakdown and corona tendencies are present also in other antenna circuit components, such as frequency-changing switches or relays, lead-in insulators, etc.

It is an object of the present invention to provide a novel antenna system requiring the application of lower voltages than would be ordinarily applied to a conventional single-wire antenna, using a radio transmitter of the same power output, and to provide an antenna system which is of substantially increased efficiency, in which the formation of corona at high altitudes is reduced or eliminated and in which no difficulty is experienced with arc-over at high altitudes.

These and other advantages are obtained by employment of a tubular-type antenna which is conducting around its periphery and which desirably may provide one or more rings with a plurality of longitudinal elements electrically

connected thereto, and it is an object of the present invention to employ a tubular-type antenna associated with a portion of an airplane formed of electrically non-conducting material, such as a plastic material, laminated plywood, etc. Such a portion will usually be hollow and may be at any one of a number of positions in a so-called "plastic" airplane. For example, it may represent a portion of the fuselage, a portion of a boom extending between airfoil sections or between an airfoil section and a control element, or a portion of the wing or other airfoil of the airplane. It is an object of the present invention to mount an antenna on such a section, as by attachment thereto or embedding therein, and to provide an antenna which occupies a minimum of space and which can be associated directly with a monocoque-type portion or section formed of non-conducting material, as by being of a shape corresponding generally to a cross-sectional shape of such a portion or section.

It is a further object of the invention to provide a new relationship between an antenna and a non-conducting or non-metallic portion of an airplane, whereby the antenna can be made to reinforce and strengthen this portion.

A further advantage of the invention is that the space inside the hollow non-conducting portion, and consequently inside the antenna, can be fully utilized for storage, cargo, or baggage purposes provided these do not extend beyond the electrical ends of the antenna. This is possible because there is no electric field inside the antenna of the invention.

The portion of the airplane which carries the antenna of the invention is desirably electrically isolated from electrically-conducting portions of the airplane. For example, a portion of the major structure of a so-called "plastic" airplane is formed of electrically conducting material and serves as a ground for radio signalling purposes. It is desirable that this electrically conducting portion of the major structure should not be too closely coupled with the antenna, and it is an object of the present invention to effectively isolate the antenna and its associated portion of the airplane formed of non-conducting material so as not to interfere with radio signalling.

Usually, however, it is desirable that control means, such as metallic cables, pipes, etc., extend between positions fore and aft or on opposite sides of the section providing the antenna. It is an object of the invention to provide electric isolation in such instances, either by disposing the control means spaced a considerable distance from the antenna, or to electrically isolate at least those portions of the control means extending adjacent or through the antenna. In the double-boom type of airplane, it is an object of the present invention to place all such control elements as are connected to the conducting portion of the airplane serving as a ground in radio signalling in one boom, and to provide the antenna system in the other boom to secure effective isolation.

Further objects and advantages of the invention will be evident to those skilled in the art from the following description of exemplary embodiments of the invention.

Referring to the drawing:

Figure 1 is a perspective view of an airplane including a fuselage installation of the invention;

Figure 2 is an enlarged vertical sectional view of that portion of the fuselage of Figure 1 incorporating the antenna;

Figure 3 is a transverse vertical sectional view, taken as indicated by the line 3—3 of Figure 2;

Figure 4 is an enlarged fragmentary view illustrating the embodiment of the invention in which the antenna is embedded in the hollow portion or section of the airplane; and

Figure 5 is a perspective view of a double-boom type airplane incorporating the invention.

Referring particularly to Figure 1, the airplane diagrammatically shown includes conventional wings 10 attached to a fuselage 11, with engine and propeller 12 disposed at the forward end and various control elements 13 disposed at the rear end of the fuselage, these control elements being, for example, a rudder 14 and elevators 15 connected by suitable control means to be under the control of a pilot seated in a cockpit 16. It is essential to the present invention that the airplane provide a portion formed of electrically non-conducting material, and the exemplary embodiment of Figure 1 exemplifies such a portion or section by the numeral 20 as forming a part of the fuselage 11. This portion 20 is hollow and may be made of any desirable non-conducting material, such as one of the well known plastics, usually of the molded type, one of the well known plywood constructions, usually consisting of a plurality of laminations of wood molded into a unitary structure by employment of suitable adhesives, typically synthetic resins, or it may be formed of any other non-metallic material so as to be a relatively poor conductor of electricity. It should be understood that all of the air-exposed surfaces of the airplane need not be formed of such material as, in some instances, the hollow portion 20 of non-conducting material can be employed with other elements of an airplane which are formed of metal.

In general, the airplane provides a major structure having one portion formed of electrically conducting material to serve as a ground for radio signalling purposes, and another portion, e. g., the hollow portion 20, which is formed of non-conducting material. The portion formed of electrically conducting material can include such elements as the engine, metal tubular engine supports (which usually extend rearward some distance), metal control cables, pipes for conducting fluid pressure for hydraulic control, etc., and such elements are conventionally electrically connected together so as to serve as a ground for the reception or transmission of radio signals. As will be hereinafter explained, it is desirable that the hollow portion 20 be electrically isolated therefrom and, in the airplane shown diagrammatically in Figure 1, this is accomplished in part by forming the hollow portion 20, or the complete fuselage 11, of non-conducting material, as is possible in the so-called "plastic" or plywood airplanes.

Disposed within the hollow portion 20, as by being positioned completely therein or embedded therein, is an antenna, indicated generally by the numeral 23. This antenna is of the tubular type and preferably conforms generally to the shape of the hollow portion 20. It is shown as of the open-ended type extending longitudinally of the hollow portion 20, and it is desirable that at least a portion of the antenna be electrically conducting completely around the periphery thereof.

The construction of the antenna shown in Figures 1, 2, and 3, includes closed rings 24 and 25 with a plurality of longitudinal members 26 extending therebetween and electrically connected thereto to form an antenna of the cage type pro-

viding a longitudinal axis which corresponds generally to the longitudinal axis of the hollow portion 20. The simplest method of constructing such an antenna is to build or mold the hollow portion 20 and then build up the antenna 23 therein by using rings 24, 25 and longitudinal members 26 formed of relatively thin strips of copper or other conducting material. These strips can be foil-like in character and, if desired, may represent mere strips of thin copper foil attached to an inner surface 27 of the hollow portion 20. For example, as suggested in Figures 2 and 3, the foil-like longitudinal members 25 may be attached to the inner surface 27 by a suitable adhesive, being equally spaced around the inner periphery of the hollow portion 20, after which the foil-like rings 24 and 25 are similarly attached after soldering or otherwise insuring a good electrical connection between these rings and the longitudinal members 26. The foil-like elements of the antenna can be bent to conform to the inner periphery of the hollow portion 20 and, as shown exaggerated in Figure 3, the rings 24, 25 may leave the inner periphery at positions where they lap the ends of the longitudinal members 26. When employing foil-like elements, it is desirable additionally to apply a thin layer of insulating material to the innermost exposed faces and, if desired, to the immediately-adjacent surfaces of the inner periphery of the hollow portion 20. This can be done easily merely by installing the antenna as previously described and then applying a thin coating of paint, shellac, or other insulating material by use of a conventional paint brush, permitting some of the material to cover the adjacent surfaces of the hollow portion 20 while insuring that all of the conducting elements of the antenna shall be coated.

Figure 2 diagrammatically shows a relay 30 providing an actuating coil 31 remotely energized to control the connecting of the antenna 23 either to a radio transmitter 32 or to a radio receiver 33. The relay 30 is shown diagrammatically as including side contacts 34 and 35, between which is disposed a movable contact 36 under the control of the actuating coil 31, this movable contact being connected by a lead 37 to the antenna 23. The radio transmitter 32 provides a ground connection 38 connected to that electrically conducting portion of the airplane employed as a ground. The output of the transmitter 32 is connected by a conductor 39 to the contact 34. Similarly, the radio receiver 33 is grounded as indicated by the numeral 40 and the input is connected by a conductor 41 to the contact 35. When the contact member 36 is in upper position, the output of the transmitter 32 is connected to the antenna, and when in lower position, the input of the receiver 33 is connected to the antenna.

With conventional antennas, considerable trouble is experienced in high altitude flying with arc-over between the contacts 34 and 35 or between or across other antenna circuit components when the transmitter is energized, as well as with corona formation at the contact 34 or adjacent the antenna when connected to the transmitter. As previously mentioned, the antenna of the present invention provides a relatively high-capacitance system and thus makes possible the use of lower transmitter voltages to overcome such difficulties. This is particularly true in the conventional band of frequencies employed for continental U. S. aircraft communication, e. g., frequencies in the neighborhood of 3 to 6 megacycles, where the antenna has been found to have unique

advantages and to be very efficient, particularly in smaller civilian or combat-type airplanes. In intercontinental or trans-oceanic flying, lower frequencies are commonly employed, e. g., within the band of about 300-500 kilocycles. The present invention has unique advantages in this band even on the largest planes. It is very desirable to employ an antenna of a length corresponding to less than one-quarter wave length of the transmitted signal and if this is done the advantage of the antenna of the invention will be about inversely proportional to frequency.

It is desirable to electrically isolate the hollow portion 20 of the antenna 23 from the electrically conducting portion of the airplane serving as the ground in radio signaling. At the same time, it is often desirable in an airplane of the type shown in Figure 1 to extend airplane control means adjacent or through the antenna 23, such control means being, for example, fluid-containing pipes, metallic cables, or electrical conductors extending from the rear control elements 13 to other parts of the airplane, usually to the vicinity of the cockpit 16. It is desirable to electrically isolate the antenna 23 from these control means so that there is no close coupling therebetween. In some instances, the control means can be formed in part of non-conducting material and in part of conducting material to solve this problem. The conducting portion may be grounded and may extend from the forward portion of the plane rearward toward the antenna 23 but should preferably terminate a short distance ahead of the ring 24 where it should meet the insulated portion, continuing rearward either as another conducting portion insulated from ground or as a non-conducting portion. For example, Figure 2 typifies a control means by a showing of a control cable 44 traversing the antenna 23. If it is desired that this control cable be metallic the desired electric isolation can be obtained by interposing an insulator 45 therein at a section adjacent, and preferably just ahead of, the ring 24. The rear portion of the cable 44 need not include an additional insulator, though this may be employed if desired. Alternatively, the forward section of the control cable can be made of metal and that portion traversing and extending rearward from the antenna 23 may be formed of non-conducting material. In the type of airplane shown in Figure 1, it is usually desirable to isolate electrically not only the hollow portion 20 but all portions of the tail structure, and this isolation involves merely insulating conducting portions of the control means or tail structure from the electrically conducting portion of the main structure which serves as a ground. If the entire tail structure is thus isolated electrically from the remainder of the plane it is often advantageous to connect all metal portions of the tail structure to the antenna. This increases its capacity and length.

In the embodiment shown in Figures 1 to 3, rings 24, 25 and the longitudinal members 26 can be made of such thickness as to serve as a reinforcing of the hollow portion 20 which, if desired, may be of a monocoque-type construction. Even better reinforcing results can be obtained by employment of the construction shown in Figure 4, which is very desirable in many instances as completely protecting the antenna structure while at the same time serving a desirable reinforcing function. Here, the rings 24, 25 and the longitudinal members 26 are embedded in the wall of the hollow portion 20 and

the antenna lead 37 may extend from embedded position contacting the antenna to an exposed position inside the hollow portion 20 for connection to the relay 30. If this hollow portion is made of laminated plywood, the antenna structure can be assembled prior to the final molding, the rings and longitudinal members being disposed between laminations which are subsequently molded or otherwise attached together. For example, in a molded plywood construction, the antenna elements are merely positioned correctly with regard to the inner laminations, for instance, before applying the outer laminations, and the entire unit is then subjected to heat and pressure to mold the antenna structure within the wall, making it indestructible and free from any danger of breakage.

Alternatively, the antenna members may be embedded closer to the external surface of the hollow portion 20, or, in fact the antenna members may be laid along and cemented to the external surface, rather than the internal surface as suggested in Figures 1 to 3. In this instance the rings 24, 25 and the longitudinal members 26 may be covered with a layer of insulating material to protect them from the air stream. Such external positioning of the tubular type antenna is to be distinguished from any proposal to apply foil-like plates to exposed surfaces of an airplane, e. g., a fabric wing. Such proposals do not produce the advantages of a tubular-type antenna and the electric field adjacent such a plate-type antenna would surround it on all sides, in contradistinction to the present invention where the electric field is entirely external of the tubular-type antenna and not on the inside thereof. Attachment of the antenna to the external surface of the hollow portion 20 is advantageous in those instances where it is desired to eliminate nearly all of the dielectric losses caused by the presence of non-conducting material in the electric field of the tubular-type antenna. The internal mounting suggested in Figures 1 to 3 usually offers no practical disadvantage in the connection and the dielectric losses are usually not significant but such losses can be further reduced, if desired, by the external mounting.

The number of longitudinal members 26 is not critical. Usually, it is desirable to dispose these members substantially equally around the periphery of the rings 24, 25 and any number of longitudinal members from three to six may be advantageously employed. There is little increase in efficiency through use of more than six longitudinal members but it will be understood that the members may be considerably wider than as shown in Figures 1 to 4 and that, if desired, these members may extend into close proximity with each other or be electrically integral to provide a completely tubular structure. Also, if desired for reinforcing or other reasons, the antenna members may comprise wires, pipes, or bars electrically connected together in a configuration corresponding to the hollow portion 20. All such possibilities are contemplated in the term "tubular-type" antenna herein-used.

Figure 5 illustrates the application of the invention to a double-boom type airplane in which the major structure includes a wing 70 carrying a short fuselage 71 with booms 75 and 76 extending rearward from the wing 70 and carrying a tail structure 77 which carries known airplane control elements, such as rudders, elevators, etc., the two engines being carried at the forward ends of the booms 75 and 76 and driving the plane

through propellers 78. In this type of construction, the antenna 23 previously described may be incorporated to extend inside and longitudinally along the boom 75, as suggested in Figure 5, this boom providing the hollow portion 20 previously described. In this instance, the invention comprehends that all control means formed of electrically conducting material and connected to the metallic portion of the airplane serving as a ground shall extend in the other boom 76. This boom 76 is shown broken away to illustrate diagrammatically three such control means comprising cables 81, 82, and 83 operatively connected to control elements of the tail structure 77. In this instance, such control cables are isolated by being spaced a sufficient distance from the antenna 23 so as not to be closely coupled therewith, and it is not necessary that they provide electrically insulated sections as suggested in Figure 2. I believe it to be new to place all of such control means in one boom and to incorporate the antenna in the other of the booms. I believe it to be new also to dispose all of the control means in one boom, irrespective of antenna placement. It should be understood, however, that the invention does not preclude the use of properly isolated control means in the boom 75 extending through the antenna 23, particularly if such control means are of a non-conducting character.

The invention finds particular use in combat-type airplanes where destruction of the antenna system of the invention is practically impossible without destroying the airplane itself. Any one or a number of the elements of the antenna can be pierced or broken by gun fire without rendering the radio system inoperative or reducing its efficiency appreciably. However, even aside from military use, the invention has far-reaching advantages, particularly in high altitude flight and particularly because of the previously mentioned ability to fully utilize the space inside the antenna-carrying portion and inside the antenna itself for storage, cargo or baggage purposes.

It is contemplated that the appended claims shall be broadly construed within their terms and within the disclosure herein presented.

I claim as my invention:

1. In an airplane providing a major structure having a portion formed of electrically conducting material to serve as a ground for radio signalling purposes and another tubular portion formed of non-conducting material such as a plastic material or plywood, the combination of: an open-ended tubular-type radio antenna formed of electrically conducting material and conforming generally to the peripheral shape of said tubular portion, the ends of said tubular-type antenna being spaced longitudinally along said tubular portion formed of non-conducting material; and means for capacitively isolating said last mentioned portion and said antenna from said portion of said major structure serving as a ground.

2. A combination as defined in claim 1, in which said open-ended tubular-type radio antenna provides at least one portion forming a continuous current path around the periphery of said tubular-type antenna.

3. In an airplane providing a major structure having a portion formed of electrically conducting material to serve as a ground for radio signalling purposes and another tubular portion formed of non-conducting material such as a plastic material or plywood, the combination of: a peripherally-continuous, open-ended, tubular-

type radio antenna formed of electrically conducting material and positioned to extend within said tubular portion with its open ends spaced longitudinally along said tubular portion, the peripheral configuration of said tubular-type antenna conforming substantially to the cross-sectional configuration of said tubular portion, said antenna being capacitively isolated from said portion of said major structure serving as a ground.

4. In combination with an airplane having a tubular portion of its major structure formed of laminated plywood and comprising a plurality of laminations bonded together, a tubular radio antenna electrically continuous around its periphery and formed of thin electrically-conducting material permanently bonded in place between the laminations of said plywood, said tubular portion extending axially beyond each of the ends of said tubular antenna.

5. In combination with an airplane having a tubular portion of its major structure formed of electrically non-conducting material such as plastic material or plywood, a radio antenna comprising two closed ring means not greatly different in peripheral size and formed of electrically-conducting material, each of said ring means being bonded to and disposed around the axis of said tubular portion, and a plurality of electrically-conducting longitudinal members bonded to said tubular portion and electrically connected to said closed ring means at positions around said axis.

6. A combination as defined in claim 5, in which said longitudinal members comprise thin foil-like elements bonded to a surface of said tubular portion throughout their lengths and substantially paralleling the outer surface of said tubular portion.

7. A combination as defined in claim 5, in which said ring means of conducting material and said longitudinal members comprise thin foil-like elements entirely and permanently embedded and bonded within the walls of said tubular portion.

8. In combination: an airplane including a portion formed of electrically conducting material serving as a ground for radio signalling purposes and including a hollow portion formed of electrically non-conducting material; airplane control means extending along the interior of said hollow portion and providing a first section electrically connected to said portion of said airplane formed of electrically conducting material and providing a second section operatively connected to said first section but electrically isolated therefrom and from said portion of said airplane formed of electrically-conducting material, said second section extending longitudinally within said hollow portion; and a tubular-type antenna attached to said hollow portion and of a configuration substantially corresponding to said hollow portion and extending longitudinally thereof, said tubular-type antenna surrounding said second section of said control means.

9. A combination as defined in claim 8, in which said tubular-type antenna includes a ring of conducting material of a shape conforming generally to the cross-sectional shape of said hollow portion and through which said second section of said control means extends.

10. In combination: an airplane including a portion formed of electrically conducting material serving as a ground for radio signalling purposes and including a hollow portion formed

of electrically non-conducting material; a tubular-type antenna secured to said hollow portion and disposed inside the outer surface of said hollow portion; and airplane control means extending from said portion serving as a ground to a position beyond said hollow portion, said control means including a first section electrically connected to said portion serving as a ground and a second section electrically isolated from said first section, said first section of said control means stopping short of said tubular-type antenna a sufficient distance to be effectively capacitively isolated therefrom.

11. In combination: an airplane including wing means, rear control elements and two hollow booms extending therebetween, one of said booms including a hollow portion formed of electrically non-conducting material, said airplane including a portion formed of electrically conducting material serving as a ground for radio signalling purposes; metallic control means operatively connected to said rear control elements, said metallic control means being electrically connected to said portion of said airplane serving as a ground and said metallic control means extending exclusively along the other of said booms to isolate said hollow portion of said one boom from said portion of said airplane serving as a ground; and a radio antenna disposed inside the outer surface of said hollow portion of said one boom.

12. In combination: an airplane including wing means, rear control elements, and two hollow booms extending therebetween, one of said booms including a hollow portion formed of electrically non-conducting material, said airplane including a portion formed of electrically conducting material serving as a ground for radio signalling purposes; metallic control means operatively connected to said rear control elements, said metallic control means being electrically connected to said portion of said airplane serving as a ground and said metallic control means extending exclusively along the other of said booms to isolate said hollow portion of said one boom from said portion of said airplane serving as a ground; and a tubular-type radio antenna extending along and secured to said hollow portion of said one boom.

13. In combination: an airplane including wing means, rear control elements, and two hollow booms extending therebetween, one of said booms including a hollow portion formed of electrically non-conducting material, said airplane including a portion formed of electrically conducting material serving as a ground for radio signalling purposes; metallic control means operatively connected to said rear control elements, said metallic control means being electrically connected to said portion of said airplane serving as a ground and said metallic control means extending exclusively along the other of said booms to isolate said hollow portion of said one boom from said portion of said airplane serving as a ground; and a radio antenna of generally tubular shape extending along said hollow portion of said one boom and conforming generally to the peripheral shape thereof.

14. In combination: an airplane including wing means, rear control elements, and a tubular means extending between said wing means and said rear control elements, said tubular means including a hollow portion formed of electrically non-conducting material; and a tubular-type antenna means attached to and conforming in general shape to said hollow portion, said tubular-

type antenna being of shorter length than said hollow portion.

15. In combination: an airplane including wing means, rear control elements, a portion formed of electrically conducting material serving as a ground for radio signalling purposes, and a hollow portion formed of electrically non-conducting material and disposed between said wing means and said rear control elements to electrically isolate said rear control elements from said portion serving as a ground; a tubular-type antenna means electrically isolated by said hollow portion from said portion serving as a ground; metallic control means for operating said control elements; means for electrically isolating those portions of said control means adjacent said antenna means from said portion serving as a ground; and means for electrically connecting these isolated portions of said control means to said antenna means.

16. In an airplane having a portion of its major structure formed of electrically-non-conducting material such as plastic material or plywood, said

portion being of tubular shape at, between, and beyond two axially-spaced positions, the combination of: a first ring formed of electrically-conducting material secured to and conforming in shape to said tubular-shaped portion between said axially-spaced positions but closer to one such position than to the other; a second ring formed of electrically-conducting material secured to and conforming in shape to said tubular-shaped portion at another position between said axially-spaced positions but closer to the other of such positions; said first and second rings being spaced from each other; and strips of electrically-conducting material extending between said first and second rings and electrically connected thereto, said rings and said strips forming a cage-type antenna.

17. A combination as defined in claim 16, in which said rings and said strips are embedded within and bonded to said electrically-non-conducting material to be protected from contact and to reinforce said tubular portion.

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