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HIGH-PERFORMANCE AIRFOIL ANTENNA

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Fig. 1.

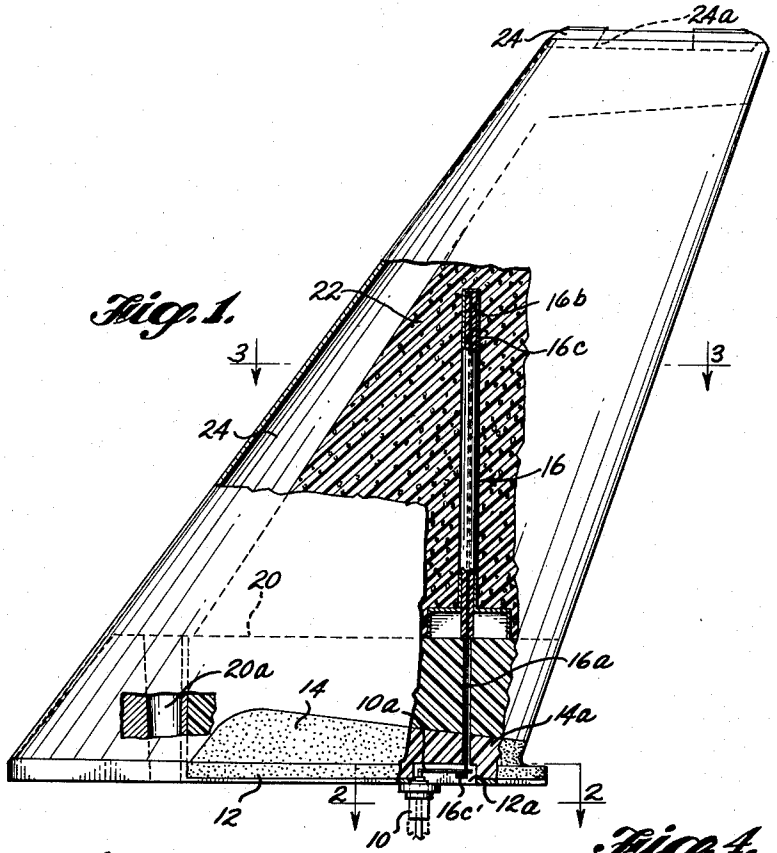


Fig. 3.



Fig. 2.

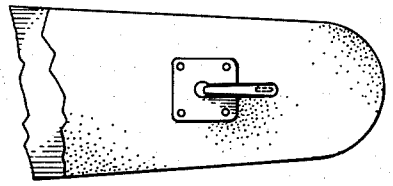
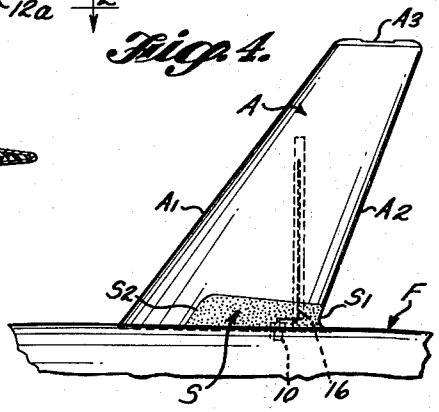


Fig. 4.



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HIGH-PERFORMANCE AIRFOIL ANTENNA

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This invention relates to improvements in aircraft UHF and VHF antennae of fin-like configurations. More particularly it concerns an improved airfoil unipole-type antenna adaptable for external mounting on high-performance aircraft, missiles and other vehicles. The invention is herein illustratively described by reference to its presently preferred form; however, it will be recognized that certain modifications and changes therein with respect to details may be employed without departing from the essential features involved.

An object hereof is to provide such antennae of simple, relatively inexpensive construction, achieving a substantially uniform omnidirectional radiation or receiving pattern, and being comparatively easily and rapidly tuned using a single tuning element.

A further object is to devise a fin-like slotted airfoil antenna the frontally and laterally exposed surfaces of which may be formed solidly of metal, hence capable of resisting erosion forces incident to high-performance aircraft operation.

Another object is to provide such antennae of broadband characteristics and high power handling capacity.

An important object is a structurally efficient low-drag slotted airfoil antenna capable of withstanding heavy lateral loads through of light-weight construction, and which may be provided with internal warm air duct space for anti-icing purposes.

A related object is to achieve the various purposes set forth in a slotted airfoil antenna structure the radiation surfaces of which are grounded directly to the supporting base, such as the structure of an airplane or missile, and which are energized across the slot through a D.C. blocking capacitance, thereby protecting associated circuits against interference or damage from lightning discharges.

As herein disclosed, the novel antenna system comprises a fin-like airfoil structure integrally formed of sheet metal and having a single edge-opening elongated slot located adjacent to and extending along the base or ground plane surface from which the mounted antenna projects in transverse relationship. The inductively reactive slot terminates intermediate the edges of the airfoil and tapers in width toward the open end of the slot. The antenna is energized through a transmission line extending from the ground plane surface and capacitance coupled to the radiation surfaces beyond the slot preferably by means of a coaxial tuning stub internal to the airfoil and situated adjacent the open end of the slot.

As shown, this sheet metal structure is of hollow form, enclosing a space the forward portion of which serves as an anti-icing warm air duct and the remainder of which may be at least partially filled with foamed plastic for structural reinforcement. A base fitting on the airfoil carries a transmission line coupling element, and serves as a means to mount the airfoil in the aircraft structure. The slot is closed by a filler of thermoplastic substance made flush extriorly with the airfoil surface.

These and other features, objects and advantages of the invention will become more fully evident from the following description by reference to the accompanying drawings.

FIGURE 1 is a side view of the antenna in its presently preferred form.

FIGURE 2 is a sectional view taken on line 2—2 in FIGURE 1.

FIGURE 3 is a sectional view taken on line 3—3 in FIGURE 1.

FIGURE 4 is a side view at smaller scale showing the antenna installed.

Referring to the drawings, antenna A in the example is of fin-like airfoil configuration. Its swept-back leading edge A1, and its aft edge A2 extends transversely to the aircraft structure surface F upon which the antenna is mounted. Conductive surface F serves as reflective base or ground plane for the antenna. Structural integrity and strength with lightness of weight is achieved by the hollow form of the airfoil presenting an exterior conductive surface comprised of continuous sheet metal except for the slot S which is occupied by solid dielectric faired to the metal surface.

Slot S is of elongated form extending generally parallel to ground plane surface F and is preferably located immediately adjacent to surface F. The slot, open at both sides of the airfoil, has one end S1 which opens at the airfoil edge A2. Its opposite closed end S2 is situated intermediate airfoil transverse edges A1 and A2. In referring to the sides and one end of the slot as being "open," it will be recognized, of course, that reference is being made to the electrical condition and not necessarily to physical openness, since for reasons of structural strength and low-drag coefficient it is desired that a continuous faired external airfoil surface be presented by the antenna. However, it will be seen that virtually all frontally and laterally exposed surface area of the antenna is or may be solid metal, the narrow surface area of the slot being situated primarily aft of the chord of maximum thickness. As a result erosion is not a problem with this antenna.

Antenna energization is provided through a coaxial transmission line coupler **10** mounted on and extending through the metal mounting plate **12** to which the antenna structure is joined and by which it is mounted on the aircraft structure. The center conductor of this coaxial fittting is connected to a strip or rod **10***a* which extends aft along the mounting plate in an open channel **14***a* formed in the plastic filler material **14** occupying the slot. An open coaxial line tuning stub **16**, designed to present a capacitative reactance, i.e. less than a quarter wavelength long, at the operating frequency extends generally chordwise into the airfoil interior and has a longitudinally adjustable center conductor **16***a* slidably received in an insulative sleeve **16***b* held in the outer conductor **16***c*. This center conductor extends into sliding contact with feed strip **10***a* and its end **16***c'* is formed to be grasped through opening **12***a* in order to move the conductor longitudinally. When adjusted to resonance the center conductor is soldered to strip **10***a* and the channel **14***a* and opening **12***a* are filled with a potting compound.

Electrically and physically conductor **16***a* is positioned to extend transversely across the slot S near its open end S1. As a capacitative reactance it appears in an external circuit (i.e. through coaxial coupler **10**) as a D.C. blocking condenser interposed in series with the antenna A and electrically resonant with the latter. The tuning stub outer conductor **16***c* is grounded to the metal antenna structure which in turn is grounded directly to the aircraft structure F. Thus lightning discharges incident upon the antenna find a direct low impedance path to the aircraft structure around the "open" slot S and are kept from the electrical circuits (not shown) to which the antenna is connected through transmission line fitting **10**.

Structurally the sheet metal antenna skin is supported by fitting onto a metal boss **20** on base plate **12**. A light-weight reinforcing foamed plastic insert **22** largely occupies the remaining interior space except for an open duct or channel **24** extending along the leading edge A1 and tip A3 as a warm air duct for anti-icing purposes. A bore **20***a* in fitting **20** carries air into this duct whereas an opening **24***a* formed in tip fitting **24** discharges the air. Coaxial tuning stub **16** is received in a bore in foamed plastic insert **22**.

In the typical installation an aperture is formed in the aircraft skin and the antenna inserted outwardly through this aperture. The aperture conforms in shape and size with the root cross-section of the airfoil. In consequence the mounting plate **12** underlies the aircraft skin metal immediately surrounding the aperture and is riveted thereto and preferably bolted to internal structure of the airframe or joined to the airframe.

The disclosed airfoil or fin-like antenna is a broadband unipole device. Broadbandedness is achieved by the taper of the slot and its relationship to the cooperating conductive surface configurations. The shape of the slot in other respects is not especially critical. For example, the slot corner formed at its closed end need not be rounded for electrical reasons but can be squared if desired. Likewise the height, width and thickness relationships of the airfoil can vary. When they are varied there will be an effect on operating band and bandwidth; however, for example, increasing the airfoil thickness increases the bandwidth by extending both ends of the operating band, yet low-drag requirements for high-performance aircraft use impose a practical limitation on thickness. Widening the airfoil has a similar effect, but use of this method to increase bandwidth is subject to aerodynamic limitations. Minimum permissible slot length is governed electrically by the lowest operating frequency desired. Minimum permissible antenna length measured from the slot to the antenna tip is governed by a similar consideration. Minimum permissible slot width, i.e. measured from ground plane outward, is governed primarily by maximum power handling capability requirements and to some extent by the maximum "Q" tolerable (i.e. a narrower slot reduces the antenna bandwidth).

In general the antenna feedpoint should be located intermediate the ends of the slot and for optimum results should be placed near the slot's open end.

Variations in shape of the fin-like antenna are also permissible from the electrical standpoint. For example, instead of an airfoil configuration a rectangular cross-sectional form with squared corners may be used. As viewed from a side aspect, the antenna can be rounded convexly, square or rectangular. The projecting edges may be parallel with each other and may be perpendicular to base plane F instead of being swept back as shown. In fact, a somewhat broader bandwith is attainable by use of a lesser sweep angle.

Inasmuch as the longest dimension of the antenna between the slot and the antenna tip governs maximum wavelength at the lower end of the antenna's operating frequency band the slot should be located immediately contiguous to the antenna base or ground plane and in fact have its longitudinal edge adjacent thereto be defined by such ground plane. This permits the antenna structure to be made as a minimum-projection airfoil suited to high-performance aircraft requirements. However if the requirement of minimum projecting length

of the antenna is not imposed, the slot's edge adjacent to the ground plane may be offset outwardly therefrom.

The practical, simple, relatively low-cost antenna of the described configuration and structure demonstrates very satisfactory electrical characteristics in terms of broad bandwidth and very high (approximately 98%) radiation efficiency. Great strength is also achieved against lateral loading, and a simple and effective means to direct warm air through the forward portion of the structure for anti-icing purposes without interfering with the structural integrity of the unit. A convenient simple means to adjust and tune the antenna to resonance at a selected median operating frequency is also afforded.

These and other aspects of the invention will be evident from a study of the disclosed embodiment in light of the foregoing specifications thereof.

We claim as our invention:

1. A high-frequency antenna comprising a conductive fin-like antenna structure adapted for mounting in transversely projecting position relative to a conductive surface, said structure having leading and trailing projecting edges and an elongated slot therein extending generally parallel to such conductive surface, said slot having one end opening at one projecting edge of the fin-like structure and the other projecting edge of said structure being of uninterrupted conductive material, and means extending from said surface to energize the antenna structure comprising a conductor electrically insulated from the structure and coupled thereto for high-frequency energy transfer at a location adjacent the open end of the slot through a capacitance which is substantially resonant with said structure at the operating frequency.

2. The antenna defined in claim **1**, wherein the fin-like structure is of hollow sheet metal airfoil configuration and the slot is substantially filled with dielectric material and has a taper in the width thereof with its narrowest portion adjacent said open end.

3. The antenna defined in claim **2**, wherein the fin-like structure forms a hollow warm air duct internally thereof extending along the forward edge, the slot being located aft of said duct.

4. The antenna defined in claim **2**, wherein the structure further comprises a mounting base upon which the sheet metal configuration is mounted, and the capacitance comprises a coaxial stub tuner contained within the airfoil configuration, said tuner having an outer conductor grounded to the airfoil structure and having a center conductor connected to said conductor electrically insulated from the structure and adapted by its adjusted position in the outer conductor to tune the antenna structure.

5. An antenna as defined in claim **1** wherein said structure has a single elongated slot.

6. An antenna as defined in claim **1** wherein said capacitance is adjacent said open end.

7. An antenna as defined in claim **1** wherein said open end is adjacent to said trailing edge.

References Cited by the Examiner

UNITED STATES PATENTS

2,826,756	3/58	Cary	343—708
2,834,961	5/58	Lear	343—705
2,908,000	10/59	Robinson	343—708
2,949,606	8/60	Dorne	343—708

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