The present invention relates to an antenna which may be installed in a flat surface structure such as in the wing and stabilizer surfaces of an aircraft. The antenna of the type of the present invention may be installed without impairing in any way the strength, efficiency or operation of the structure of the plane or other place where the installation is made. This application is a continuation of copending application Serial No. 449,717 filed August 27, 1959, now abandoned.

While slot antennas were tried by the applicant for this purpose, they offer structural difficulties because the necessary length of the slot, particularly at the lower frequencies, makes it difficult to provide structures without cutting a main spar or other element of the structure. In the present invention a flush type of antenna set in the surface is provided without any necessity of modifying the structure of the main spar or other principal structural members in the stabilizer or wings of the plane.

The present invention a hole is cut in the skin or surface of the stabilizer or other element in which the antenna is to be mounted, and in this hole which may be rectangular in shape, or of any other suitable shape, is mounted and riveted a smaller rectangular metal sheet in such a way that an insulated gap of uniform width separates the skin of the stabilizer or other structure which is of metal from the rectangular metal sheet formed as an island member within the hole structure. A piece of fiber or other insulating material may cover the island member and the gap and provide a smooth covering surface.

Such antenna structure may be fed by a coaxial cable with one conductor of the cable connected to the metal sheet on one side, and the other conductor of the cable connected to the outer metallic surface opposite the point of connection of the cable to the metal sheet.

The radiation properties of such an antenna depend upon the dimensions of the structure of the antenna in terms of width, length and upon the point at which the coaxial feeder or other feeder for supplying power is connected across the gap.

If the island formed by the metallic sheet has a vertical axis of symmetry and the feeder connection is made along the vertical axis of symmetry, the structure will radiate vertically polarized waves.

If the feeder is connected along a horizontal axis of symmetry, the structure radiates horizontally polarized waves.

This, however, is a relatively crude statement referring only to the principal plane of radiation. It becomes more accurate when the properties of the structure are so chosen that the overall length of the gap separating the surrounding skin from the island within as measured from the feeder around the gap to the feeder again is between one-half wavelength and a wavelength.

When the overall length of the slot is approximately one-half wavelength, the following behavior is observed. The slot acts like a transmission line. Along the slot there is a standing wave. The maximum voltage is developed at a point opposite the point of feed. The voltage across the gap next to the feeder is relatively low in comparison to the voltage existing across the slot on the opposite side of the feeder.

Under these conditions the portion of the slot near the feeder contributes only a small part to the total radiation. The portion of the slot or gap opposite the feeder contributes the main portion of the radiation. The portions of the slot which are perpendicular or run across from the portion of the slot where the feeder is connected to the opposite side of the slot, radiate waves which are 180° out of phase with each other in a direction normal to the skin. Therefore, these portions of the radiation in general cancel out in the direction normal to the skin. As the radiation of the portion of the slot opposite to the feed portion is large compared to that of the feed portion, the radiation of the portion opposite to the feed portion comprises the principal portion of the radiation of the antenna. This analysis holds true where the overall length of the slot or gap is a half wavelength. Where the length of the slot or gap is in the neighborhood of a wavelength, the portion of the slot in the vicinity of the feed and the portion of the slot opposite to the feed are in the same phase in the direction normal to the skin and therefore will radiate additively in this normal direction. The radiation of the portions of the slot connecting the first two main portions are 180° out of phase with each other in the direction normal to the skin and therefore tend to cancel one another. In addition the radiation of power from these last two mentioned portions of the slot are relatively low, (1) because the voltage minima occurs at the center of the slots, and (2) because the voltage on opposite sides of the voltage minima are in opposite directions so that neither of these two sections of the slot connecting the other sections would radiate anything in the direction of the normal, even individually.

The conditions which exist when the overall length of the slot is between one-half wavelength and a wavelength are intermediate of the two conditions just considered. Thus by and large, the principal radiation is always either from the section of the slot opposite to the section which is fed, or is from the section which is fed and the section opposite to it, and the antenna itself radiates waves which are polarized primarily in the direction of the axis of symmetry which passes through the feeder.

For the reasons which have been set forth above, the antenna of the present invention is particularly well suited for installation in a vertical stabilizer of an aircraft for providing vertical or horizontal polarization.

Such antennas for lower frequencies, such as 100 megacycles instead of being a dimension of 5 ft. in length, may be made as small as 15° to 30° for the size of the island.

It is further possible with the antenna of the present invention to provide a construction which does not need a cavity in back of the slot, since the island antenna of the present invention seems to be relatively insensitive to the size and shape of the cavity behind it. In fact when two island antennas are used, one on each side of the vertical stabilizer, there is no need for any cavity in the back of each antenna. Further the island antenna of the present invention is relatively broad band and can be made broad band by relatively direct means of compensation.

Without further describing the theory, principles and object of the present invention, the invention will be more specifically described in connection with the drawings attached hereto showing embodiments of the invention as actually constructed and used.

In the drawings:

FIG. 1 shows an antenna structure of the present invention in a vertical stabilizer connected in such a way as to radiate horizontally polarized waves.

FIG. 2 illustrates diagrammatically the construction installed in a vertical stabilizer on both faces of the stabilizer for radiating horizontally polarized waves.
FIG. 3 is an enlarged diagrammatic representation of FIG. 2 and, FIG. 4 shows the structure of a balun which may be used in connection with FIGS. 2 and 3.

In the structure shown in FIG. 1, 1 indicates the outer metallic skin of a stabilizer of an aircraft or other metallic surface in which the island antenna is installed. 2 indicates a metallic island which is surrounded by the skin of the stabilizer. An air gap 3 is formed between the surface 1 and the surface 2. This air gap extends all around the island 2 and it may be of uniform size. Fiberglass or some similar insulating or non-conductive plate 4 may be riveted by means of a series of rivets 5 to the surface of the stabilizer and by means of a series of rivets 6-6 to the surface of the island. This plate may be attached on the outer surface of the stabilizer, or it could be attached on the inner surface of the stabilizer whichever is more practical for structural reasons. The air gap 3 may be filled with insulating material forming a part or flange of the covering member holding the island 2 in place.

A concentric feeder 7 having an inner conductor 8 and an outer conductor 9 may be used to feed the antenna with the outer conductor connected to the outer surface of the stabilizer and the inner conductor 8 connected across the gap to the island as for instance at a point 10.

In the structure shown in FIG. 1, if the wavelength of the gap is approximately one-half wavelength within the operating range at the frequency at which the antenna is fed, a maximum will be attained on the vertical side C in the vicinity opposite the feed point at 10 and a minimum will be presented in the vicinity of the feeder. This means that most of the radiation will occur on the side C of the air gap rather than on the side A. Therefore, the radiation of the gaps A and C will be predominantly normal to the skin on the outer surface or stabilizer as used on an airplane and will be horizontally polarized as viewed in FIG. 1.

The radiations in the sections B and D of the gap will be in opposite directions and therefore will tend to cancel one another out.

If the feed, instead of being on the axis Y-Y in FIG. 1 were on the axis X-X, the minimum radiation would be either in sections B or D and the radiations in the sections A and C would be opposed to one another and cancel one another out. Under these conditions the radiations will be vertically polarized rather than horizontally polarized as previously set forth.

In FIG. 2 a vertical stabilizer of a plane is shown somewhat less perspective with two island antennas 11 and 12 both fed on one side at substantially the mid-point of the upright section of the gap. In these antennas the chief sections of radiation at a half wavelength, would be in the vertical sections of the gap 13 and 14 and the radiation of both antennas would be horizontally polarized and radiate horizontally polarized waves.

In the drawing of FIG. 2 there is shown a balun 15 connected to the feed line. The connection of FIGURE 3 may be used for an omnidirectional pattern. In this case the impedance presented to the balun is equal to the impedances of the antennas connected in series.

If the balun is arranged in accordance with the construction of FIG. 4, it presents a capacitive shunt reactance at high frequencies and an inductive reactance at lower frequencies.

The balun in this way improves the impedance spread of the antenna over the frequency range. A balun sufficiently for the desired compensation used in instrumentation purposes from 108 megacycles to 132 megacycles was about 6" long and 2" in diameter, full scale. Furthermore the Standing Wave ratio without any further connections (such as a transformer) would be below about 4 to 1.

In the structure shown in FIG. 3, there is shown two island antennas at 11 and 12 in FIG. 2, each having the same rectangular gap 13 and 14 respectively fed by coaxial cables 16 and 17 with the inner conductors 18 and 19 connected to the islands 20 and 21 on the inside of the gaps 13 and 14 respectively, with compensating capacitors in the form of shunt condensers across the transmission lines between the points of feed P and G. The condensers may be short lengths of coaxial transmission line with one conductor connected to the respective ones of feeds 11 and 12 and the other, to the respective ones of conducting sheets 20 and 21. The broken lines above P in FIG. 3 indicate the location of such capacitors.

The baluns 15 may be of the type shown in further detail in FIG. 4 consisting of outer cylindrical shell 22 with an inner coaxial feed line 23 having an inner conductor 24 and a compensating parallel section 25 generally of the same size as the outer coaxial conductor 26 and connected to it at its upper end through a capacitor 27. The upper ends of both sides of the balun may have outer and inner conductor sections 28 and 29 providing a balanced feed for antenna sections on both sides of the stabilizer.

The conductor 25 as indicated in FIG. 4, will at its top end be connected to the inner conductor 24 of the coaxial cable 26 forming the metallic skin of the stabilizer and the inner conductor 29 connected to the top plate 30 of the balun, while the outer conductor 31 of the coaxial cable 28 will also be tied to the top plate 30. The inner conductor 32 of the outer conductor 28 will go through the top plate 30 and connect to the top end of the conductor 25 which has no inner conductor in its inside, while the inner conductor 33 of the coaxial cable will connect to the outer conductor 23 within the balun. The balun is fed at its bottom through the coaxial cable projecting therefrom, which comprises the outer conductor 23 and the inner conductor 24 extending upward through the coaxial cable within the balun at the left.

The antennas on both sides of the stabilizer may be used together for horizontally or vertically polarized radiation or they may be used individually with one connected for horizontally polarized radiation and the other connected for vertically polarized radiation.

As will be understood from the invention herein described, the antenna is of a flush mounted type and will not interfere in any way with the operation of the plane nor in any way weaken the stabilizer because of its small size.

What is claimed is:

1. In combination with a conductive airfoil having opposite generally parallel conductive surfaces in an aircraft, a pair of substantially parallelly aligned antennas mounted in each surface of said airfoil, said antennas having aligned faces parallel to said sheets, means forming a dielectric gap of uniform width about each sheet in the plane of the respective airfoil surface having a length dimension of between a half and a whole wave length in the range of the operating frequency, a pair of coaxial lines each feeding said antenna across said gap at corresponding positions in a plane dividing said rectangular sheets into congruent rectangles, each of said positions defined by a pair of feedpoints on opposite sides of and immediately adjacent to said gap, whereby an additive radiation field may be obtained in the plane of said airfoil polarized generally parallel to said plane, a balance having first and second balanced terminals, an unbalanced terminal and a plurality of reference terminals with means for maintaining said reference terminals at a common potential, first and second unbalanced transmission lines coupling a respective one of said antennas between a respective balanced and unbalanced terminal, and a third unbalanced transmission line for exchanging energy with said unbalanced terminal.

2. A device as set forth in claim 1 and further comprising means for establishing additional shunt capacity across the points of feed of said antennas.

3. An aircraft antenna operative over a frequency range centered about a prescribed high frequency com-
prising, a vertical stabilizer on said aircraft having nearly parallel vertical conducting airfoils, each formed with equal area opposed rectangular openings, a pair of like rectangular conducting sheets, means including insulating material for maintaining a respective conducting sheet centered within each of said rectangular openings insulatedly separated from said conducting airfoils to define a pair of opposed circumferential gaps each surrounding a respective conducting sheet, each of said gaps being symmetrical about respective orthogonal pairs of axes lying in the plane of a respective airfoil, a pair of coaxial transmission lines each having an inner and outer conductor, said conductors of a respective line being respectively connected to an associated airfoil and an associated one of said conducting sheets at points immediately adjacent to and separated by an associated one of said gaps, said points of connection across one gap being directly opposite to said points of connection across the other and lying on one of said axes, the circumferential length of each gap being approximately one-half to one wavelength of energy within said frequency range, and means for exchanging energy with said coaxial transmission lines so that the potential developed at the feed point of one conducting sheet is oppositely sensed with respect to that developed at the other conducting sheet feed point referenced to the potential on said conducting airfoil.

4. A radiating system operative over a relatively wide frequency range about a center high frequency comprising, a pair of closely-spaced opposed generally parallel conducting surfaces substantially maintained at a common potential and formed with congruent openings therein, a conducting plate within each of said openings generally coplanar with and insulatedly separated from a respective one of said conducting surfaces to define first and second congruent perimetrical insulating gaps surrounding a common axis, the length of each of said gaps being a half wavelength to a wavelength for frequencies within said wide frequency range and means for establishing oppositely sensed potentials with respect to said common potential at opposed points on said conducting plates immediately adjacent to a respective gap to establish a standing wave pattern a half to a full wavelength long for frequencies within said frequency range in both said gaps and provide substantially omnidirectional radiation characteristics about an axis generally parallel to said surfaces and perpendicular to said common axis.

5. A radiating system in accordance with claim 4 wherein said means for establishing comprises, first and second coaxial transmission lines each having inner and outer conductors, a balun having first and second balanced terminals, an unbalanced terminal and a plurality of reference terminals, the first and second transmission line inner conductors respectively coupling said first and second balanced terminals to respective ones of said opposed points on the respective conducting plates, the first and second transmission line outer conductors respectively coupling reference terminals to respective ones of the remaining opposed points.

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