

April 23, 1963

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3,087,159

MICROWAVE SCIMITARED ANTENNA

Filed Jan. 8, 1960

Fig. 1.

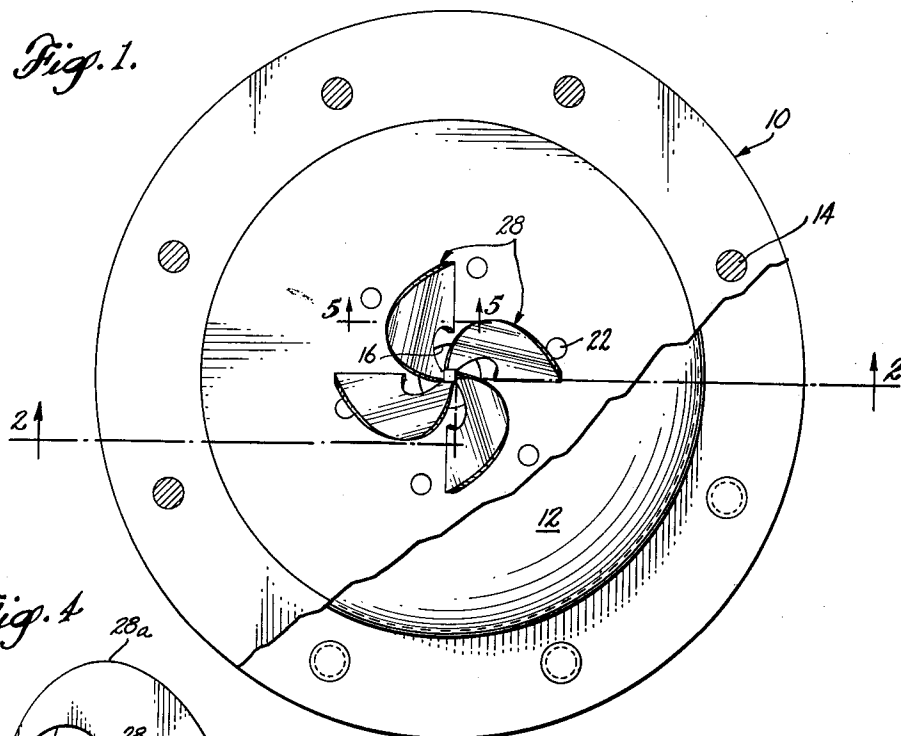


Fig. 4

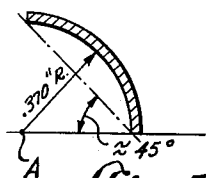
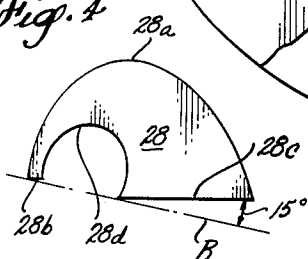


Fig. 5.

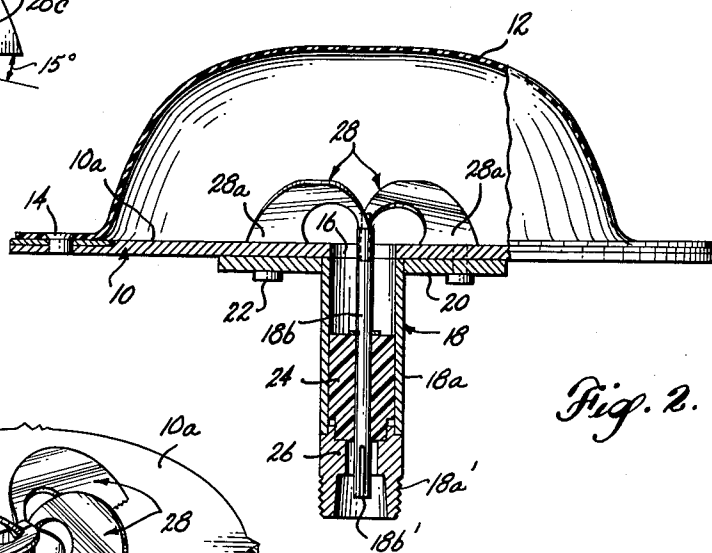


Fig. 2.

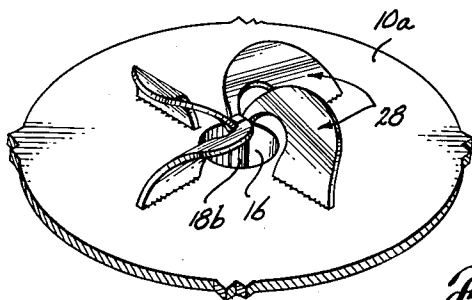


Fig. 3.

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3,087,159

MICROWAVE SCIMITARED ANTENNA

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Filed Jan. 8, 1960, Ser. No. 1,196

4 Claims. (Cl. 343-848)

This invention relates to a new and improved microwave antenna configuration suitable for aircraft use where omnidirectional and dual polarization characteristics are necessary or desirable. The invention is herein illustratively described in its presently preferred form; however, it will be recognized that certain modifications and changes therein with respect to details may be made without departing from underlying essentials involved.

One important application for ultra-high frequency antennae with omnidirectional and dual polarization characteristics is in electronic countermeasures system. In that case, as well as certain others, it is also important that the antenna function effectively over a broad band of frequencies. Further, because of aerodynamic requirements in aircraft applications it is essential that the antenna be very compact and that it be required to project only slightly if at all into the slipstream. As, of course, in most all antenna applications, efficiency is essential.

In general the present invention has for its broad object the attainment of these objectives and characteristics in a microwave antenna.

Other objects include lightness of weight, simplicity, ease of manufacture and assembly, simplicity of mounting and of feeding the antenna, rigidity against distortions due to vibrations and the like which could impair operating characteristics, versatility for mounting of the same on any of different portions of an aircraft, adaptability of the configuration to successful operation in different frequency bands merely by scaling up or scaling down the dimensional specifications, and related objectives.

Certain prior proposals for scimitared-element antennae are described in Aviation Week, July 14, 1958, page 75 et seq., but for omnidirectional, dual polarized radiation patterns attainable advantageously as in the present system no prior suitable configurations of this type are known to have been developed or suggested.

As herein disclosed the invention features a cluster of four scimitared conductive radiator strips arranged in quadrature with the broad ends of the strips joined to a conductive base surface and with the narrow ends of the strips mutually convergent upon the terminus of an energizing transmission line conductor which passes through an aperture in the conductive surface located centrally within the cluster. As an important feature, the strips are inclined to the surface, all in the same sense or direction around the cluster. As a further important feature, the strips are curved concavely on the side facing toward the conductive surface.

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

FIGURE 1 is a top view of the antenna with a portion of its housing broken away to show antenna details.

FIGURE 2 is a sectional side view of the antenna taken on line 2-2 of FIGURE 1.

FIGURE 3 is a perspective view of the antenna proper.

FIGURE 4 is a face view of one of the scimitared elements prior to bending.

FIGURE 5 is a sectional view taken on line 5-5 in FIGURE 1 showing the curvature of the bent elements, and the inclination thereof to the conductive surface.

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As illustrated in the drawings, the antenna comprises a conductive surface 10a comprising the exposed or outer surface of the metal base plate 10. A dielectric protective dome 12 is secured to the plate 10 as by means of rivets 14 passing through a marginal flange on the dome. The plate has a central aperture 15 in registry with the open end of a coaxial line fitting 18 which serves as a feed line for the antenna and approaches the plate from its back side in perpendicular relationship therewith. The coaxial line outer conductor 18a carries an integral mounting flange 20 which is secured by screws or rivets 22 to the back side of the plate 10. In the illustrated embodiment the coaxial line section 18 comprises a center conductor 18b having a slitted outer end 18b', whereas the corresponding end 18a', of the outer conductor is threaded, both the slitting and the threading being common in standard coupling arrangements for coaxial transmission lines. An insulating bead 24 supports the center conductor 18b within the outer conductor where a stepped configuration 26 on the interior of the outer conductor serves as an impedance transformer which transforms the apparent impedance of the antenna as viewed through the coaxial line to the desired impedance for maximum efficiency in energizing the antenna. The nature of this impedance transformer and the degree of transformation required will depend upon the net effective impedance resulting from the antenna configuration itself, upon the characteristic impedance of the line and upon the output impedance of the energy source in the case of transmission, or the input impedance of the receiving source in case of energy reception. The design considerations here involved are well known.

The center conductor 18b projects centrally through aperture 16 and into the interior of the dome 12 by a short distance beyond the plane of the surface 10a as shown. The amount of projection affects antenna impedance as do other features of antenna configuration. This projecting end of the center conductor 18b serves as a terminal and connecting point for the inner ends of a cluster of four tapered scimitared strips or elements 28 which are arranged in quadrature and which have broad or base ends 28a joined to the surface 10a on radial lines which pass through the axis of the center conductor 18b and which are disposed at 90 degrees to each other. The particular form and arrangement of the scimitared element cluster is at the heart of the invention.

For ease of understanding, the scimitared configuration will be described in what is presently considered to be its optimum form to operate over a frequency band (C-band) from 5,000 megacycles to 11,000 megacycles. It should be understood, however, that the design requirements are essentially the same for operation in other frequency bands (such as X-band or K-band), but that the physical scale of dimensions of the elements will be decreased or increased in accordance with the operating wave lengths chosen.

In FIGURE 4 there is depicted a development view of one of the four scimitar elements 28 as the same would be cut, for example, from a flat sheet of metal, such as 0.06 inch stock. The precise thickness of the metal is not critical although it should be thin in relation to the major physical dimensions of the completed elements. In the case of C-band applications a thickness of 0.06 inch thickness is suitable. The outer edge 28a preferably follows an Archimedean spiral curve, the radius of which increases progressively from the inner or smaller end 28b of the scimitar to the outer or base end 28c. The inner edge 28d is concavely rounded. The contour followed by this inner edge is not critical, that is, it may comprise a portion of a circle, of an ellipse, of a parabola or of a second Archimedean spiral.

Its effect is primarily one of determining impedance of the antenna as viewed from the coaxial line 18. The scimitar shape is an exaggerated shape in which the smaller end 28b has a width which comprises a small fraction (such as on-tenth more or less), the width of the base or broad end 28c.

The desired configuration of the scimitar element is completed by bending the same in a cylindrical form, such as a circular cylinder, centered at an axis A (FIGURE 5) which is disposed parallel to a line B (FIGURE 4) contained in the plane of the original scimitar blank and lying at 15 degrees to the base edge 28c, as shown. For the particular operating frequency band mentioned above, the radius of curvature is approximately 0.370 inch. It will be recognized, however, that the curvature may vary somewhat and that it may be elliptical or some other regular curvature instead of circular. The particular curvature and its radius affect antenna impedance but have no critical or marked effect on radiation characteristics as such.

The four elements are installed on the surface 10a and the projecting end of the center conductor 18b, as by brazing, silver soldering, or other suitable bonding procedure assuring good electrical continuity between the interconnected conductive elements. The scimitars are canted or sloped in relation to the plane of the surface 10a preferably by an angle of approximately 45 degrees (FIGURE 5), as measured on the chord of the arc of curvature of the individual elements. The slope is the same for each element progressing around the series, with the result that the cluster somewhat resembles a ship's screw-type propeller. Slanting of the scimitar elements at approximately 45 degrees to the antenna base surface 10a produces approximately equal vertical and horizontal polarization components in the field pattern of the antenna. The approximately 45 degree angle is about optimum for the stated purposes of the invention. If this angle is decreased to a value below approximately 30 degrees not only is the vertical polarization component proportionately decreased, which is usually undesirable, but phasing problems arise and the resulting effect on radiation problems arise and the resulting effect on radiation pattern is adverse (i.e., it becomes lobed). If the angle is increased above 45 degrees the horizontal polarization component decreases and the vertical polarization component increases. If the angle is as much as 90 degrees to the surface 10a, there is still some horizontal polarization component but the pattern is so greatly lobed and irregular as to be undesirable. Thus, for most applications requiring omnidirectional, dual polarization characteristics the 45 degree slant of the scimitar elements is substantially optimum, whereas variations, if the circumstances tolerate them, should not exceed plus or minus 15 degrees. However, if omnidirectional characteristics and predominant polarization in one plane or the other is acceptable or even desirable, then the angle of slant may be varied more greatly.

Furthermore, the curvature or bend in the scimitared strip elements transversely to their length is desirable as a means of assuring an omnidirectional pattern. For the frequency band specified above, the radius of bend of 0.370 inch was arrived at experimentally. As previously intimated, however, this is not a highly critical dimension, nor is the form of the bend (i.e., circular, elliptical, etc.); nevertheless, if the radius is decreased appreciably below that figure, say to 0.250 inch, antenna impedance is adversely affected, viz., it becomes less in the higher frequency portion of the operating band and greater in the lower frequency portion of such band. Moreover, if the radius is increased materially above the prescribed optimum, such as to 0.500 inch, serious lobing or irregularities in the radiation pattern will occur. This cylindrical bend formed in the scimitared elements has

been described as occurring about an axis parallel to the line drawn in FIGURE 4 at 15 degrees to the base edge 28c of the elements. It is found that a variation of plus or minus 5 degrees from the 15 degree relationship is tolerable and that the effect of excessive variation is to produce serious lobing in the radiation pattern. Lobing occurs at the higher operating frequencies in the assigned band when the 15 degree angle is reduced to near zero, whereas if it is materially increased to a value above 20 degrees serious phasing problems likewise occur which adversely affect the omnidirectional characteristics.

It is important that the scimitared elements be arranged essentially as shown in the figure, that is, that there be four such elements arranged in quadrature relationship with the smaller ends of the scimitar elements terminating on the end of the central conductor 18b and the larger ends joined to the surface 10a so as to feed the elements with identical phasing and amplitude and from a common source so that each is subjected to identical feed circuit parameters. If an attempt were made to feed the scimitar elements individually, as by feeding them at their smaller ends if the elements were reversed end-for-end, i.e., with their larger ends abutting, serious phasing problems would arise and it would be very difficult to obtain co-phasing of the energizing currents in the elements so as to produce a true omnidirectional pattern. Likewise, if only three scimitared elements are used, or any other odd number for that matter, phasing problems arise which result in interference effects producing lobing of the radiation pattern. More than four elements is unnecessary because with four a substantially ideal omnidirectional dual polarization radiation pattern is obtained.

With reference to the curvature of the edge 28a it is found that an Archimedean spiral curve is desirable, the spiral radius increasing progressively from the smaller end 28b toward the larger end 28c. It is found that a constant-angle type spiral configuration is less desirable than the Archimedean spiral because of a reduction of band width caused by the substitution. The inside curve 28d governs the impedance characteristics of the antenna, and as previously suggested it may be circular, elliptical, or of some other rounded form, the average effect of which is to produce the desired input impedance when taken with the other elements influencing the antenna impedance as a whole. The clearance between the edge of the aperture 18 and the inside edges of the scimitared elements is not especially critical, but of course as the average distance between the edge 28d and the terminal end of the coaxial line 18a is increased the effective impedance which the antenna presents to the line is increased. It is desirable that the inside edge curve 28d have an edge length of more than one-quarter wave length at the highest operating frequency in the band for which the antenna is designed to operate and that the outside curve 28a be of a length less than one-half wave length at the lowest operating frequency in the assigned band. With these dimensions the antenna represents essentially a capacitive load on the transmission line. The value of impedance depends upon the specific size and configuration of the elements and for that reason different impedance transformer arrangements, represented in the example by the arrangement 26, may be required in the transmission line.

As will be recognized from the discussion hereinabove concerning the radius of bend of the scimitared elements, if the elements are made flat, yet are sloped to the surface 10a, such as at an angle of 45 degrees, dual polarization will occur but the resultant radiation pattern will be lobed and the band width will be reduced.

The operating theory of the invention may be explained on a qualitative basis by observing that the distribution of current along the length of the scimitar ele-

ments (i.e., especially their outer edges 28a) is presumably the same as in the case of a shorted lossless transmission line. This current distribution along any element follows a sinusoidal variation of amplitude, but it is of essentially constant phasing along the length of each of the scimitar elements inasmuch as these elements have a length which is less than one-half wave length at the operating frequency. Because of the symmetry of arrangement, the common feed, the identical location in the various branches of points at which the currents therein are relatively in phase, mutual reinforcement of the electromagnetic field occurs in the current band or region in which these in-phase currents exist, resulting therefore in a marked increase in attenuation of the traveling wave due to radiation. In any case, and the full theoretical explanation may yet be improved and refined, the disclosed combination of elements is found in practice to produce an electromagnetic field polarized in both vertical and horizontal planes and which is omnidirectional in both planes as desired.

The antenna is highly suitable for aircraft use or similar applications, especially in the microwave regions such as the C and X bands. Because of its small size and compact form it presents negligible drag when projecting the slight distance which it needs to project into the slipstream. It is efficient and, as will be seen, is of relatively simple construction. Due to the form of the scimitared elements, especially when bent in the optimum configuration, the antenna is extremely stiff and durable and its characteristics are not influenced appreciably by any vibrational effects which may occur in the surrounding structure of the aircraft.

These and other aspects of the invention will be recognized by those skilled in the art on the basis of the foregoing disclosure of the presently preferred embodiment thereof.

I claim as my invention:

1. Microwave antenna means comprising a base presenting an exposed conductive radiation surface having a feed aperture therein, electrical transmission line means joined to the opposite side of said base and having a feed conductor one end of which projects at a generally central location through said aperture in a direction substantially perpendicular to said surface, and a cluster of tapered conductive strips of scimitared form having their narrow ends commonly joined to the projecting end of the feed conductor and their broad ends joined to said base surface in substantially uniform angularly spaced relationship around said aperture, and with the individual scimitared elements arched outwardly between their connections to said feed conductor and said surface, each of said scimitared elements having a portion of one face thereof facing generally away from the radiation surface, said scimitared elements being substantially uniformly in-

clined to said surface at an acute angle and in the same sense around the cluster and being curved concavely on a substantially cylindrical contour on the side thereof facing said surface, with the axis of curvature being at least approximately parallel to the broad end edge of each element joined to the surface.

2. The antenna means defined in claim 1, wherein the axis of curvature is substantially parallel to an imaginary line lying in the general body plane of the strip before curvature and converges with said end edge at an angle of approximately fifteen degrees, such convergence being in the direction generally toward the small end of the scimitared element, and wherein the strips are inclined at approximately forty-five degrees as measured between the chord of such curvature and the underlying radiation surface.

3. The antenna means defined in claim 2, wherein there are a total of four scimitared elements arranged in quadrature, the broad end edges thereof being joined to the exposed surface of the base along mutually perpendicular lines passing through said conductor, and wherein the outer longitudinal edges are of approximately Archimedean spiral form.

4. Microwave antenna means comprising a base presenting an exposed substantially flat conductive radiation surface having a feed aperture therein, electrical transmission line means joined to the opposite side of said base and having a feed conductor one end of which projects at a generally central location through said aperture in a direction substantially perpendicular to said surface, and a cluster of tapered conductive strips of scimitared form totalling four in number having their narrow ends commonly joined to the projecting end of the feed conductor and their broad ends joined to said base surface around said aperture in quadrature relationship related to said conductor as a common center, and with the individual scimitared elements being arched outwardly between their connections to said feed conductor and said surface, their outer longitudinal edges being substantially in the form of an Archimedean spiral, said strips being inclined to the surface at approximately forty-five degrees all in the same sense around the cluster and being concavely curved transversely to their length on the side thereof facing said surface.

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