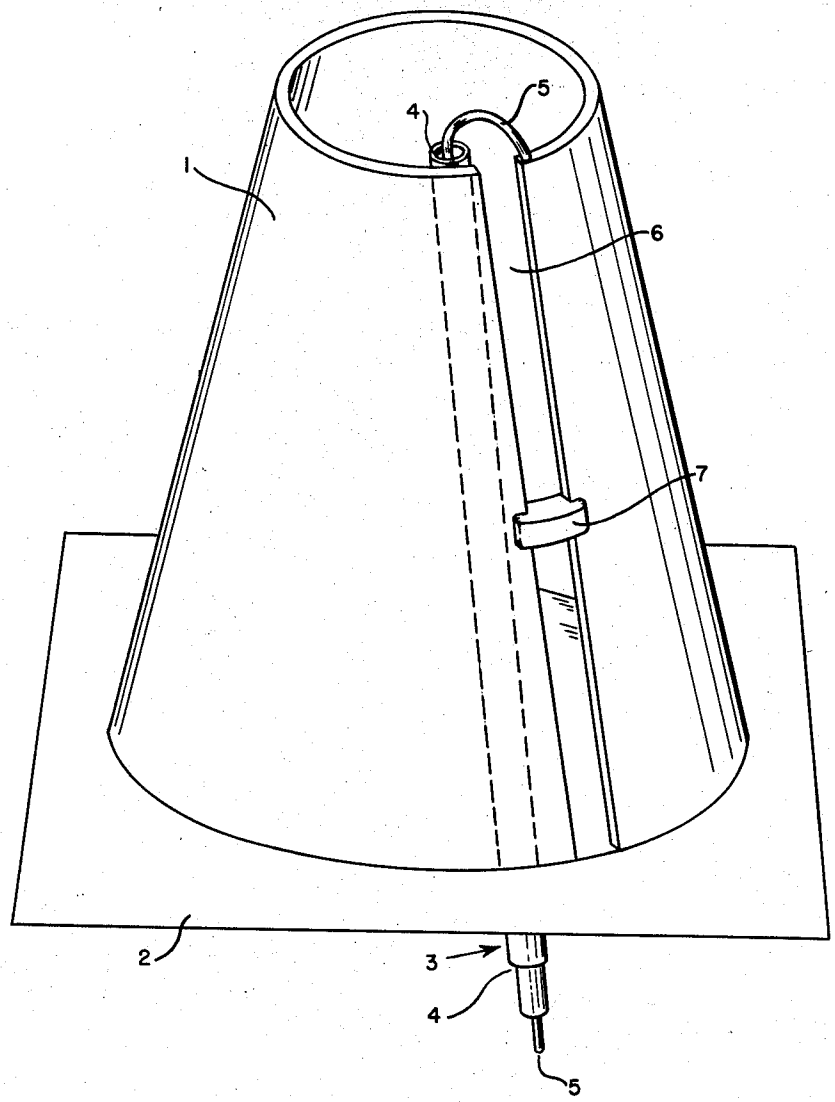
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SPLIT TRUNCATED CONE ANTENNA

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INVENTOR

PRICE M. KEELER

BY

William D. Hall.

ATTORNEY

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SPLIT TRUNCATED CONE ANTENNA

Price M. Keeler, Hempstead, N. Y., assignor to the United States of America as represented by the Secretary of War

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This invention relates generally to electrical apparatus and more particularly to a radio frequency antenna whose horizontal pattern is relatively free of nulls and is nearly circular in shape.

For certain purposes it is desirable to radiate radio frequency energy equally in all directions. That is to say, although there are advantages in antenna directivity for certain purposes, for other purposes it is quite undesirable. It is sometimes desirable that substantialy equal signal strength be emanated from a radiating element in every direction. For example, it might be expedient for a hovering aircraft to play the part of a broadcating station. Such a plane, in cruising about, would have frequently to change direction in order not to fly away from the zone of its operation. If its antenna system were directive, movements of the plane would be felt in some receivers as changes in signal strength.

On type of antenna, which might seem to have the proper form of radiation pattern, is a quarter wavelength dipole protruding from the bottom of the aircraft and pointing toward the gound. It certainly would radiate energy in all directions in the horizontal plane. However, since the polarization of this antenna is vertical, its use might not always be appropriate if the antenna systems of most receivers, associated with such a broadcasting system, were horizontally polarized.

It is an object of this invention to provide an antenna having a substantially circular radiation pattern in a plane that may be considered horizontal and is, in fact, a plane perpendicular to the axis of the main element of this antenna. It is also an object of this invention that this antenna offer a favorable input impedance for efficient power transfer from ordinary feed lines. It is a further object of this invention that this antenna be horizontally polarized. It is a further object of this invention that this antenna be adaptable for operation over a relatively wide band of frequencies.

Generally, this invention comprises a structure in the form of a truncated cone conductive over at least its outer surface except for what may be a non-conductive strip running the length of the structure with its axis substantially coplanar with the axis of the tube. The width of this strip is small by comparison with its length. The interruption in the continuity of conductivity of the outer surface may take the form of a physical split or slit cut from the conical structure (in the location described above) and particularly so if solid sheet metal

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is used to form this conductive element. This split conical structure is fed with radio frequency energy applied from suitable transmission line means to selected points on each side of the slit and communicated by way of the edges of the slit to substantialy all of said conductive surface; said conductive surface radiates said electromagnetic energy with its electric vector polarized in a plane, or planes, substantially perpendicular to the axis of said conical element.

Other objects, features, and advantages of this invention will suggest themselves to those skilled in the art and will become apparent from the following description of the invention taken in connection with the single figure of the accompanying drawing in which:

The figure is an isometric view of the embodiment of this invention.

Referring now to the drawing, the split truncated cone 1 is composed of thin sheet metal. It might be formed by cutting sheet metal along two curved lines, drawn approximately as parallel segments of two concentric circles, and along two radii, each one drawn as a radius common to said two circles and to intersect said two curved lines near their respective ends (a pattern comonly employed in making simple lamp shades), and by bending said sheet metal, so cut out, into substantially the form of a truncated cone, until the two straight edges formed by said radii nearly touch and form, between them, a narrow slit the axis of which is coplanar with the axis of said cone. The larger end of thus truncated cone abuts against, and is attached to, a substantially flat element 2 which may be another piece of sheet metal, specially selected for the purpose, or may be, in effect, furnished by some conducting portion of the bottom surface of the aircraft on which this antenna may be installed. Flat element 2 serves an obvious mechanical function in adding to the rigidity of truncated cone 1. Besides this, it affects the overall behavior of the radiating element by serving as a "ground plane." Coaxial transmission line 3, having an outer conductor 4 and an inner conductor 5, may be led to the inside of truncated cone 1 by coming through a hole, in flat element 2, situated near an edge of slit 6. When the feed line is installed in this manner, it may be led along said edge to its opposite end (to the place where cone 1 remains open as shown in the figure). Outer conductor 4 may be mechanically and electrically connected to one edge of slit 6 either along the full length of the slit or at its above described

end. In the embodiment, and patricularly as shown in the figure, this connection is made at the end of outer conductor 4 and is made between outer conductor 4 and the end of one edge of the slit. It may be made by soldering or brazing or by any other suitable conventional means. In the figure this connection is shown as a solid inked-in area at a point of contact between the connected parts. Inner conductor 5 extends beyond outer conductor 4, at this point, and is bent over and electrically joined to the opposite edge of the end of slit 6. Shorting bar 7 is adapted to slide between, and to have good electrical contact with, the edges of slit 6, thus short circuiting those edges at any point where it is positioned. Conventional types of spring contactors may be used and incorporated into shorting bar 7, or it may be fashioned as a clampable element which can, at will, be mechanically loosened, positioned, and retightened.

The length of slit 6 should be somewhat greater than one-half of one wavelength corresponding to the lowest intended operating frequency. While the velocity of propagation along slit 6 may sometimes be exactly equal to the speed of light, it may vary so as either to be somewhat less or somewhat greater than that velocity. Therefore, in most cases, this dimension will be somewhat different physically than electrically. Generous proportioning as to the length of the slit may be advisable in order to give due allowance to this fact. Then, in actual operation, the shorting bar may be set as a point on the slit which is distant from the feed point by an exact effective half wavelength even if the velocity of propagation along the slit is greater than the speed of light.

It has been found empirically that the approximate circumference of the conical element should be near to one whole wavelength in space. It is likely that reactance loading effects inherent in this metallic structure (which can be looked upon as a single turn of a wide strip of metal) may affect the electrical length measured around the outside of the tube, between the edges of the slit, so that the effective electrical length is really quite different than the physical measurement. However, that may be, it has been determined as a fact that in the case of a cylindrical structure the physical size of the circumference should be about equal to $\frac{8}{10}$ of the longest wavelength in space. Since the antenna is in the form of a truncated cone, that size would be correct for the circumference which the outer surface of said cone would form on an intersecting plane perpendicular to the axis of said cone and lying about midway between its ends. Where the truncated cone is proportioned in this way, the device becomes adjustable over a broader frequency band than if a cylindrical shape were used. For as the shorting element is moved close to the feed point, to adjust the length of the slit to a high operating frequency, then the circumference of the used portion of the radiator (which might have been correct for a lower frequency) would probably be incorrect and would be too large. Instead, the average circumference of the used portion of the radiator becomes progressively smaller at the same time that the distance along the slit is reduced.

With proper adjustment of shorting bar 7 this radiating element presents a good impedance match to a low impedance feed line.

The foregoing portion of this disclosure has indicated some of the controlling facts about the structure of this antenna. The following portion is a suggested explanation as to some of the principles of its operation. The R. F. potential difference between the conductors of the feed line when applied between the open ends of the slit causes a wave to travel along it toward shorting bar 7. This wave is reflected by the shorting bar and, since the attenuation of the forward and reflected waves is not very great, a standing wave is formed along the slit. If the position of shorting bar 7 is adjusted properly, the standing wave will include one whole voltage loop with voltage nulls occurring at the feed point and the shorting bar. When the slit is tuned to resonance, in this way, it offers a pure resistance load to the feed line, and the value of this load is a low one.

The phases of the R. F. potentials at different points along the slit will be practically the same though the potential differences at these points will vary according to the standing wave ratio.

The potential differences existing between the two edges of the slit will cause R. F. currents to flow around the conductive outer surface of the conical element and will cause an electric field to be set up whose lines of force will be roughly parallel to the paths of these currents. As a result, the entire outer surface will radiate R. F. energy which is polarized in a plane perpendicular to the axis of the conical element.

The cone acts as though it consisted of a number of individual loops piled up coaxially and energized in phase.

By reference to well known facts about the behavior of closed loops it could be inferred that the horizontal radiation pattern of this device, if its polarization be termed horizontal for purposes of convenience, would be rather nondirectional.

It has been observed by actual experiment that the radiation emitted by this antenna is distributed in those planes which include the axis of the tubular element so as to form radiation patterns describing the form of a figure 8 lying on its side, that is with its nulls being along the axis of the cylinder. The radiation emitted in planes at right angles to the axis (the radiation herein referred to as horizontal) forms patterns which vary with changes in the frequency applied to the antenna, without readjustment, but are generally cardiodal at higher frequencies and nearly oval at lower frequencies. However, at any frequency within its operating range this antenna has a horizontal pattern which is noticeably nondirectional and has no pronounced nulls. The radiation is, however, a little greater in a direction out of the slit from the axis than in the opposite direction or in directions toward either side.

It is obvious that the horizontal radiation pattern could be made even more circular if the slit were made to follow a helical path around the surface of the conical structure instead of a straight path coplanar with its axis.

It has been confirmed experimentally that if the radiating element is made conical in shape, like the embodiment shown herein, it is adjustable to function in an efficient manner over a broader band of operating frequencies than if it is made cylindrical.

It is obvious that it is not necessary to restrict the length of the radiating element to an effective half wavelength or less. Of course, if its length were extended beyond an effective reso-

nant half wavelength, the outer radiating surface would emit certain radiations out of phase with other radiations and they would not add up to produce the kinds of patterns in the horizontal and vertical planes described above. However, there are methods well known in prior art for meeting this problem. For example, the slit could be fed at a plurality of points so as to be excited in a plurality of sections each of which could individually be limited to a single effective half wavelength and where the feed lines would be of such unequal lengths as to cause said sections of said slit to be excited in phase.

It will be seen that the antenna herein set forth will radiate energy horizontally polarized and will do so without objectionably pronounced directivity in the horizontal plane and without marked nulls in its horizontal radiation pattern; that it presents a favorable input impedance; that it can be made adjustable over a relatively broad band of operating frequencies.

It is obvious that a great many minor variations in the details of design and of materials used in constructing antennas of this type could be embodied in it without departing from the basic principles of the invention.

Accordingly all such deviations are claimed which fall fairly within the spirit and scope of the invention as identified in the hereinafter appended claims.

What is claimed is:

1. A broad band antenna including a hollow metallic truncated cone having a length greater than one-half of one wavelength corresponding to the lowest operating frequency and an average circumference greater than a wavelength corresponding to the lowest operating frequency with a narrow slit whose axis is coplanar with the axis of said cone extending the full length of said cone, a metallic sheet reflector oriented perpendicular to the axis of said cone electrically contacting the periphery of said cone at its larger base, a coaxial transmission line a portion of which is mounted in said cone through a hole in said reflector with the outer conductor of the portion of said line contained by said cone parallel to the slit in said cone and electrically connected along its entire length to said cone near the slit in said cone and with said outer conductor terminated at the smaller base of said cone and with the inner conductor of said line extending beyond said outer conductor and terminated in electrical contact with said cone at the opposite edge of the slit in said cone at the smaller base of said cone and an adjustable shorting bar electrically connecting opposite edges of said cone resulting from the slit in said cone.

2. A broad band antenna with a plane polarized substantially circular response pattern in a plane perpendicular to its axis including a conductive sheet in the form of a truncated cone with a slit coplanar to the axis of the hollow cone, a conductive sheet reflector oriented perpendicular to the axis of said cone electrically connected to the larger base of said cone, a coaxial transmission line a portoin of which is mounted in said cone through a hole in said reflector with the outer conductor of said line terminated in electrical contact with the smaller base of said cone near one side of the slit in said cone and with the inner conductor of said line terminated in electrical contact with the smaller base of said cone near the other side of the slit in said cone and a shorting bar connected to said cone across the slit in said cone and adjustable along the length of said slit whereby said antenna has a low input impedance.

3. A broad band antenna with a plane polarized substantially circular response pattern in a plane perpendicular to its axis including a truncated substantially conical radiator with a longitudinal slit along the full length of said radiator, a sheet reflector oriented perpendicular to the axis of said radiator in electrical contact with an end of said radiator, a coaxial transmission line a portion of which is mounted in said radiator through a hole in said reflector with the outer conductor of said line in electrical contact with said radiator along one edge of the slit in said radiator and with said outer conductor terminated at the end of said radiator opposite said reflector and with the inner conductor of said line extending beyond said outer conductor and connected to said radiator at the other edge of the slit in said radiator and a shorting bar connected to said radiator across the slit in said radiator and adjustable along the length of said slit whereby the input impedance of said antenna is of a low value.

4. A broad band antenna with a plane polarized substantially circular response pattern in a plane perpendicular to its axis including a truncated substantially conical radiator with a longitudinal slit along the full length of said radiator, a reflector at one end of said radiator in a plane perpendicular to the axis of said radiator, a coaxial transmission line with its inner conductor connected to said radiator near an edge of the slit in said radiator and with its outer conductor connected to said radiator near an opposite edge of the slit in said radiator and a shorting bar connected to said radiator across said slit and adjustable along the length of said slit whereby the input impedance of said antenna is of a low value.

5. A broad band antenna with a plane polarized substantially circular response pattern in a plane perpendiculr to its axis, said antenna comprising a hollow metallic body having an outer radiating surface substantially in the form of a truncated cone with a substantially straight slit in its periphery and a transmission line comprising two conductors with one of said conductors connected to said body near one edge of said slit and with the other of said conductors connected to said body at a point on the opposite edge of the slit in said body.

6. A broad band antenna with a plane polarized substantially circular response pattern in a plane perpendiculr to its axis, said antenna comprising a hollow metallic body having an outer radiating surface substantially in the form of a truncated cone and having a longitudinal slit, a transmission line connected to said body across the slit in said body, and a shorting bar connected to said body solely across said slit, said shorting bar being adjustable along the length of said slit.

7. A broad band antenna with a plane polarized substantially circular response pattern in a plane perpendiculr to its axis, said antenna comprising a hollow metallic body having an outer radiating surface substantially in the form of a truncated cone and having a longitudinal slit therein, means coupled to said body across said slit for applying high frequency energy thereto, and tuning means coupled to said body across said slit to tune said slit.

8. A broad band antenna with a plane polarized substantially circular response pattern in a plane

perpendicular to its axis comprising a truncated substantially conical hollow radiator with a longitudinal slit, the effective electrical peripheral measurement of said conical radiator at substantially the center thereof being approximately an electrical wavelength at the mid-operating-frequency, means coupled to said radiator across said slit for applying high frequency energy thereto, and short-circuiting means coupled to said radiator across said slit and longitudinally movable therealong to adjust the effective electrical length of said slit to one-half wavelength.

9. A broad band antenna with a plane polarized substantially circular pattern in a plane perpendicular to its axis comprising a hollow metallic body substantially in the form of a truncated cone and having a longitudinal slit, the effective electrical peripheral length of said body at substantially the longitudinal center thereof being approximately an electrical wavelength at the mid-frequency of said band, and energy transmission means coupled to said body on opposite sides of said slit.

10. A broad band antenna with a plane polarized substantially circular pattern in a plane perpendicular to its axis comprising a hollow metallic body in the form of a truncated cone and having a longitudinally slit, the effective length of said slit being at least approximately equal to a half wavelength at the lowest frequency in said band, the effective electrical peripheral length of said body at substantially the center thereof being approximately an electrical wavelength at the mid-frequency of said band, energy transmission means coupled across said slit for applying high frequency energy thereto, and means to tune said slit.

11. A broad band antenna having a substantially circular pattern plane polarized in a plane perpendicular to its axis, said antenna comprising a hollow metallic body having an outer radiating surface substantially in the form of a truncated cone and having a longitudinally slit therein, the effective length of said slit being at least approximately equal to a half wavelength at the lowest frequency in said band, and energy transmission means coupled to said body on opposite sides of said slit for applying energy thereto.

PRICE M. KEELER.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,218,741	Buschbeck	Oct. 22, 1940
2,234,293	Usselman	Mar. 11, 1941
2,238,770	Blumlein	Apr. 15, 1941
2,243,136	Trevor	May 27, 1941
2,368,663	Kandoian	Feb. 6, 1945
2,369,556	Gamet	Feb. 13, 1945
2,414,266	Lindenblad	Jan. 14, 1947
2,479,209	Chu	Aug. 16, 1949
2,513,007	Darling	June 27, 1950
2,521,844	Gordy	Sept. 12, 1950

OTHER REFERENCES

Radio, December 1945, "FM–FAX skyrocket antenna," pages 38, 58, and 59.

Electronic Industries, January 1946, "Experimental FM antenna," page 126.